16

CLIMATE CHANGE RESEARCH REPORT CCRR-16

Responding to Climate Change Through Partnership

Current and Projected Future Climatic Conditions for Ecoregions and Selected Natural Heritage Areas in Ontario

Ministry of Natural Resources

Natural. Valued. Protected.

Ontario

Climate Change and MNR: A Program-Level Strategy and Action Plan

The following describes how the Ministry of Natural Resources works to contribute to the Ontario Government's commitment to reduce the rate of global warming and the impacts associated with climate change. The framework contains strategies and sub-strategies organized according to the need to understand climate change, mitigate the impacts of rapid climate change, and help Ontarians adapt to climate change:

Theme 1: Understand Climate Change

Strategy #1: Gather and use knowledge in support of informed decision-making about climate change. Data and information gathering and management programs (e.g., research, inventory, monitoring, and assessment) that advances our knowledge of ecospheric function and related factors and forces such as climate change are critical to informed decision-making. Accordingly, MNR will work to:

- Strategy 1.A: Develop a provincial capability to describe, predict, and assess the important short- (0-5 years), medium- (5-20 years), and long-term (20+ years) impacts of climate change on the province's ecosystems and natural resources.
- Strategy 1.B: Model the carbon cycle.

Strategy #2: Use meaningful spatial and temporal frameworks to manage for climate change. A meaningful spatial and temporal context in which to manage human activity in the ecosphere and address climate change issues requires that MNR continue to define and describe Ontario's ecosystems in-space and time. In addition, MNR will use the administrative and thematic spatial units required to manage climate change issues.

Theme 2: Mitigate the Impacts of Climate Change

Strategy #3: Gather information about natural and cultural heritage values and ensure that this knowledge is used as part of the decision-making process established to manage for climate change impacts. MNR will continue to subscribe to a rational philosophy and corresponding suite of societal values that equip natural resource managers to take effective action in combating global warming and to help Ontarians adapt to the impacts of climate change.

Strategy #4: Use partnership to marshal a coordinated response to climate change. A comprehensive climate change program involves all sectors of society as partners and participants in decision-making processes. The Ministry of Natural Resources will work to ensure that its clients and partners are engaged.

Strategy #5: Ensure corporate culture and function work in support of efforts to combat rapid climate change. Institutional culture and function provide a "place" for natural resource managers to develop and/or sponsor proactive and integrated programs. The Ministry of Natural Resources will continue to provide a "home place" for the people engaged in the management of climate change issues.

Strategy #6: Establish on-site management programs designed to plan ecologically, manage carbon sinks, reduce greenhouse gas emissions, and develop tools and techniques that help mitigate the impacts of rapid climate change. On-site land use planning and management techniques must be designed to protect the ecological and social pieces, patterns, and processes. Accordingly, MNR will work to:

- Strategy 6.A: Plan ecologically.
- Strategy 6.B: Manage carbon sinks.
- Strategy 6.C: Reduce emissions.
- Strategy 6.D: Develop tools and techniques to mitigate the impacts of rapid climate change.

Theme 3: Help Ontarians Adapt

Strategy #7: Think and plan strategically to prepare for natural disasters and develop and implement adaptation strategies. MNR will sponsor strategic thinking and planning to identify, establish, and modify short- and long-term direction on a regular basis. Accordingly, MNR will work to:

- Strategy 7.A: Sponsor strategic management of climate change issues.
- Strategy 7.B: Maintain and enhance an emergency response capability.
- Strategy 7.C: Develop and implement adaptation strategies for water management and wetlands.
- Strategy 7.D: Develop and implement adaptation strategies for human health.
- Strategy 7.E: Develop and implement adaptation strategies for ecosystem health, including biodiversity.
- Strategy 7.F: Develop and implement adaptation strategies for parks and protected areas for natural resource-related recreational opportunities and activities that are pursued outside of parks and protected areas.
- Strategy 7.G: Develop and implement adaptation strategies for forested ecosystems.

Strategy #8: Ensure policy and legislation respond to climate change challenges. Policy, legislation, and regulation guide development and use of the programs needed to combat climate change. MNR will work to ensure that its policies are proactive, balanced and realistic, and responsive to changing societal values and environmental conditions.

Strategy #9: Communicate. Ontarians must understand global warming, climate change, and the known and potential impacts in order to effectively and consistently participate in management programs and decision-making processes. Knowledge dissemination through life-long learning opportunities that are accessible and current is critical to this requirement. MNR will raise public understanding and awareness of climate change through education, extension, and training programs.

Current and Projected Future Climatic Conditions for Ecoregions and Selected Natural Heritage Areas in Ontario

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Summary

The changes in global climate that have been projected for this century have major implications for the composition, structure, and function of ecosystems in Ontario. In this report, we present four approaches that summarize projected changes in climate across Ontario's ecosystems at two scales: for ecoregions and for selected natural heritage areas. First, the current climatic regime or "climate envelope" for each ecoregion is summarized and mapped for three future time periods (2011-2040, 2041-2070, 2071-2100); this shows where current ecoregion climatic conditions are projected to move as the century progresses. Second, climate summaries are provided for each ecoregion for the current and three future time periods to show how climate is projected to change within the currently defined ecoregion boundaries. Similarly, current and future climate summaries are provided for 29 selected natural heritage areas. Finally, to introduce the concept of climate-related movement of flora and fauna, current and future climate envelopes are generated for 12 Ontario tree species that have a range of climate and site type preferences. The extent to which these species' climate habitats are represented across Ontario's network of natural heritage areas is shown for current and future climate. Our findings suggest that changes are in store for Ontario, with ecoregion climate envelopes projected to shift northward, becoming increasingly smaller and more scattered, and in some cases even disappearing, as the century progresses. These changes are driven by a northward shift in temperature combined with relatively stable precipitation patterns. Clearly Ontario's natural heritage areas will also be affected by these changes. For example, the annual mean temperature in Polar Bear Provincial Park is projected to increase from -4.5°C to nearly +2°C and the number of growing season degree days will more than double by the end of this century; this climatic shift would in principle make the park's climate suitable for the growth of sugar maple. This type of assessment is an important first step in projecting the effects of future climate on Ontario's ecoregions and natural heritage areas, and helps establish a basis for discussing and developing management strategies and policies to ensure the ecoregion framework remains relevant to land use planning in a rapidly changing climate. Together, these analyses provide novel perspectives on some of the challenges that resource managers are likely to face during the 21st century.

Résumé

Conditions climatiques actuelles et prévues des écorégions et de zones choisies du patrimoine naturel de l'Ontario

Les changements climatiques planétaires prévus pour ce siècle ont des répercussions importantes sur la composition, la structure et la fonction des écosystèmes de l'Ontario. Dans le présent rapport, nous présentons quatre approches qui résument les changements climatiques prévus dans les écosystèmes de l'Ontario à deux échelons : les écorégions et des zones choisies du patrimoine naturel. Nous résumons et cartographions d'abord le régime climatique actuel ou l'« enveloppe climatique » de chaque écorégion pour trois périodes à venir (2011 à 2040, 2041 à 2070, 2071 à 2100), ce qui révèle où on prévoit que les conditions climatiques actuelles de l'écorégion devraient se déplacer au cours du siècle. Ensuite, des résumés climatiques de chaque écorégion pour la période actuelle et les trois périodes à venir révèlent en quoi le climat devrait changer dans les limites de l'écorégion telles qu'actuellement définies. Nous présentons de même de tels résumés des conditions climatiques actuelles et futures de 29 zones choisies du patrimoine naturel. Enfin, en vue d'aborder le concept du mouvement de la flore et de la faune en lien avec le climat, nous avons généré les enveloppes climatiques actuelles et futures de 12 essences d'arbres de l'Ontario qui ont une prédilection pour certaines conditions climatiques et des préférences quant au type de site. Nous avons indiqué la représentation des habitats climatiques de ces espèces dans le réseau ontarien des zones du patrimoine naturel pour les conditions climatiques actuelles et futures. Nos résultats suggèrent que des changements se préparent pour l'Ontario : les enveloppes climatiques de l'écorégion pourraient se déplacer vers le nord, devenir de plus en plus petites et dispersées et, dans certains cas, aller jusqu'à disparaître à mesure que nous avancerons dans le siècle. Ces changements seront provoqués par un mouvement de la température vers le nord combiné à des configurations de précipitations relativement stables. Il est clair que ces changements auront une incidence sur les zones du patrimoine naturel de l'Ontario. Par exemple, on prévoit que la température annuelle moyenne du parc provincial de l'Ours polaire passera de -4,5 °C à près de +2 °C et que le nombre d'unités thermiques de croissance de la saison de végétation aura plus que doublé d'ici la fin de ce siècle. Ce changement climatique permettrait en principe la croissance de l'érable à sucre dans le parc. Ce type d'évaluation est une première étape importante dans la projection des effets des futures conditions climatiques sur les écorégions et les zones du patrimoine naturel de l'Ontario, et contribue à établir une base de discussion et d'élaboration de stratégies et politiques de gestion, afin de veiller à ce que le cadre de travail de l'écorégion demeure pertinent à la planification de l'affectation des terres dans une situation de changements climatiques rapides. Ensemble, ces analyses constituent de nouvelles perspectives sur des défis que les gestionnaires de ressources devront probablement relever au cours du 21e siècle.

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Introduction

Climate is a principal driver of life, and rapid climate change threatens current planetary life systems (Chiotti and Lavender 2007). Therefore, it is important to understand the known and potential effects of climate change on the ecosphere from a variety of perspectives to effectively develop and implement mitigation and adaptation programs. This report was prepared to assist Ontario's resource managers in their work to understand the potential effects of climate change at two scales: for ecoregions (Figure 1) and for selected natural heritage areas (Figure 2).

Ecosystems can be very large (the ecosphere is earth's largest ecosystem) and very small (a pond, for example), where the smaller ecosystems often fit into the larger ecosystems in some form of hierarchical relationship. This hierarchical approach (e.g., Hills 1961, Rowe 1961, Wiken 1986, Sims and Uhlig 1992, Burger 1993, Crins et al. 2009) helps resource managers deal with complex systems by dividing them into subsets with similar characteristics that can be used for decision-making at many spatial scales. While not perfect, criteria and rules with which to define and describe ecosystems as recognizable entities of space-in-time have been developed and applied for decades (Gray et al. 2009:4). For example, the boundaries of Ontario's three ecozones (continental-level ecosystems) are distinguished primarily on the basis of bedrock geology, and the 14 ecoregions nested within them are distinguished by characteristic climatic regimes and bedrock geology (Crins 2002, Crins et al. 2009). Specifically, an ecoregion is *A unique area of land and water nested within an ecozone that is defined by a characteristic range and pattern in climatic variables, including temperature, precipitation, and humidity. The climate within an ecoregion has a profound influence on the vegetation types, substrate formation, and other ecosystem processes, and associated biota that live there* (Crins et al. 2009).

Based on projections from general circulation models (GCMs) of the earth's climate under a variety of greenhouse gas emission scenarios, global temperature is projected to increase by 1.1 to 6.4°C during this century (IPCC 2007); projections for precipitation vary by region and season, but are generally in the range of ±25% (Bates et al. 2008). Given the strong influence of climate on the derivation of Ontario's ecoregional boundaries, it is unclear whether this framework will continue to be useful in natural asset management and planning, or how the ecoregion approach might be modified as the climate changes. In support of efforts to address these and many other questions, we present potential changes to the climate in all of Ontario's ecoregions.

The potential effect of rapid climate change on natural heritage areas is also concerning and uncertain. For example, natural heritage areas may no longer provide suitable habitat for resident flora and fauna as the climate changes and reproductive success may be compromised. This is particularly true for species that are rare and endangered, have limited geographic distribution, and/or migrate more slowly (e.g., plants and amphibians) than the projected rates of climate change. In this report, we present two basic approaches to explore the potential effects of climate change on natural heritage areas in Ontario. First, we summarize the current and projected future climate of selected natural heritage areas. Second, we report whether selected natural heritage areas provide a climate suitable for 12 Ontario tree species now and into the future.

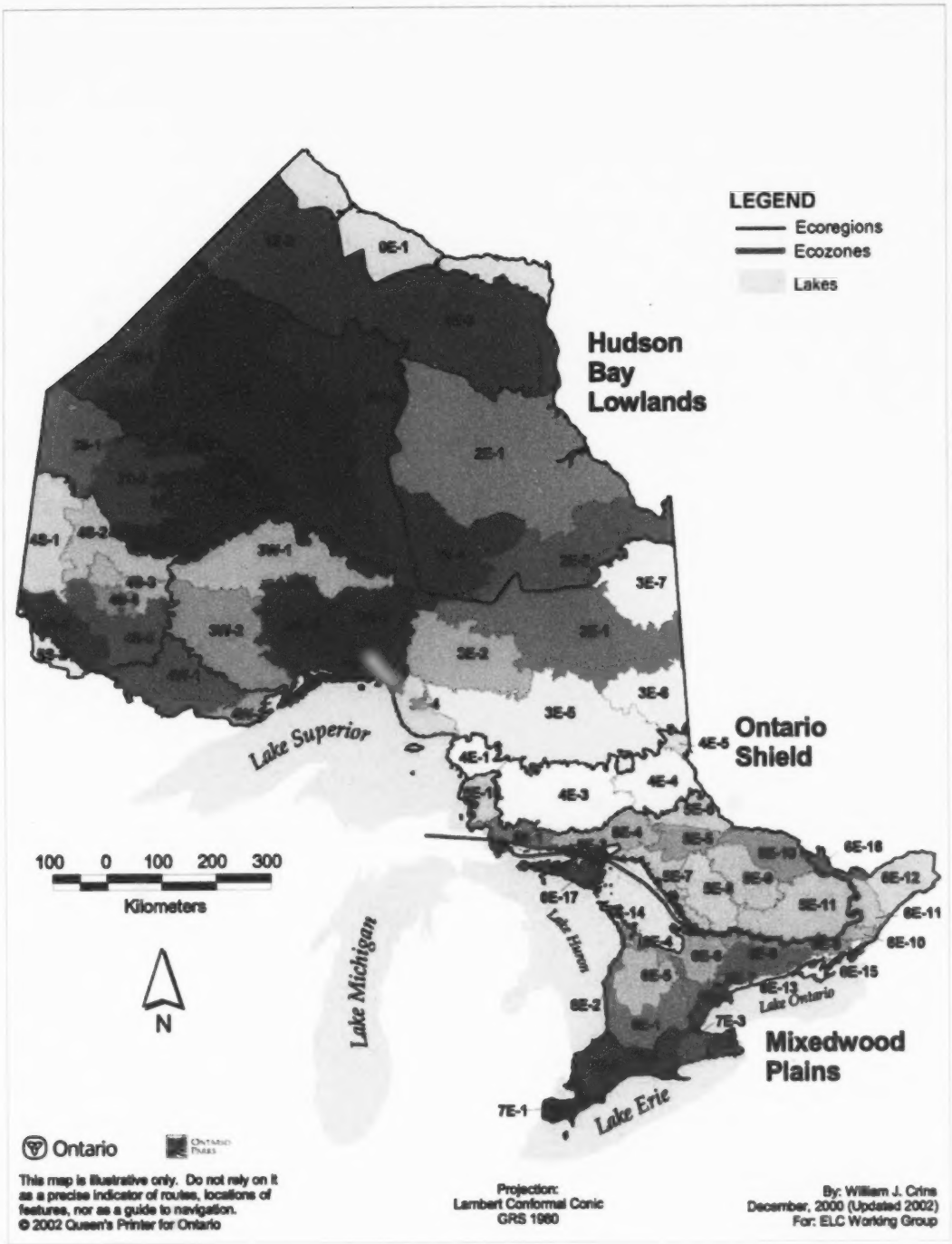
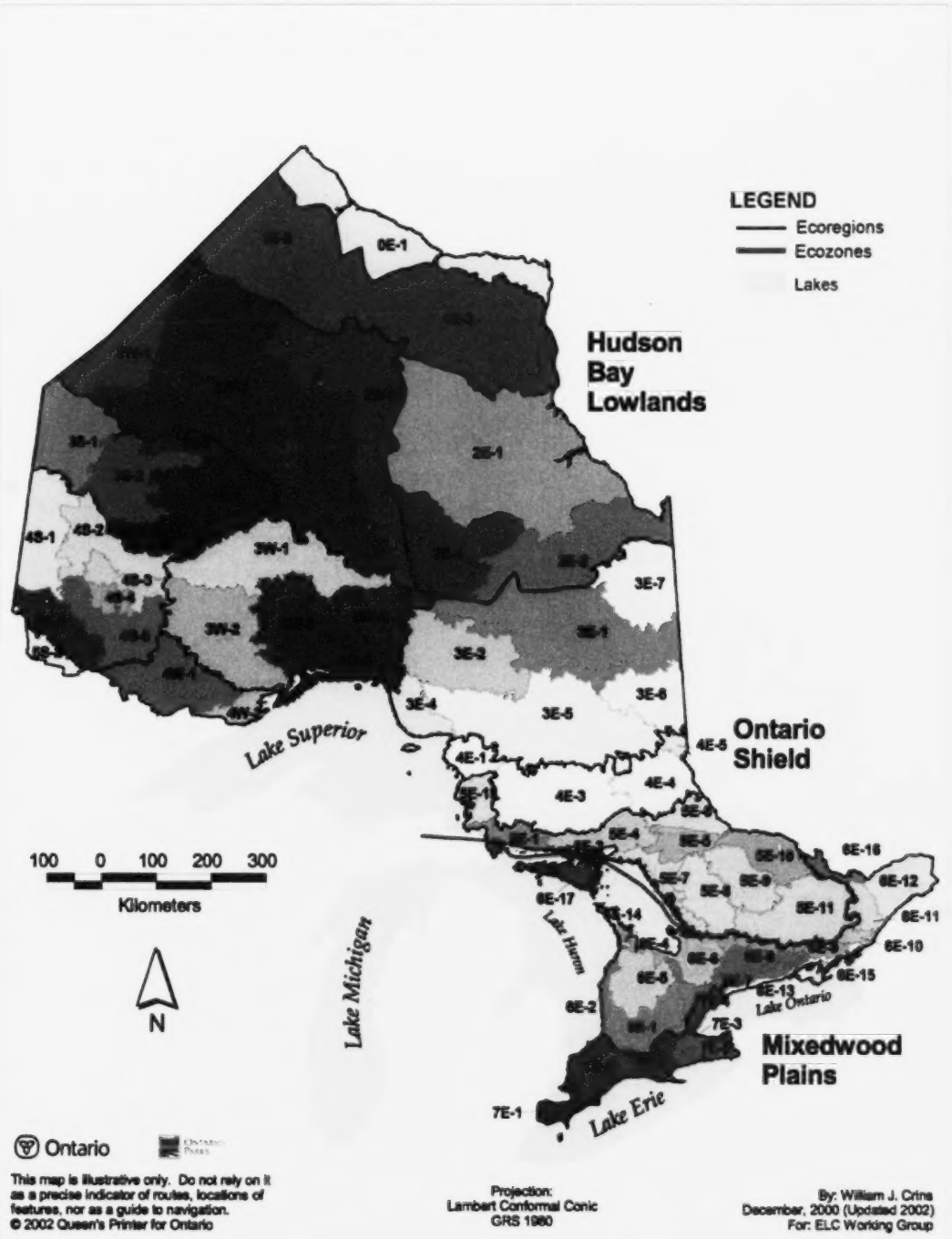


Figure 1. *The ecozones, ecoregions and ecodistricts of Ontario (Crins 2002).*

Figure 2. *The locations of natural heritage areas selected for this study.*



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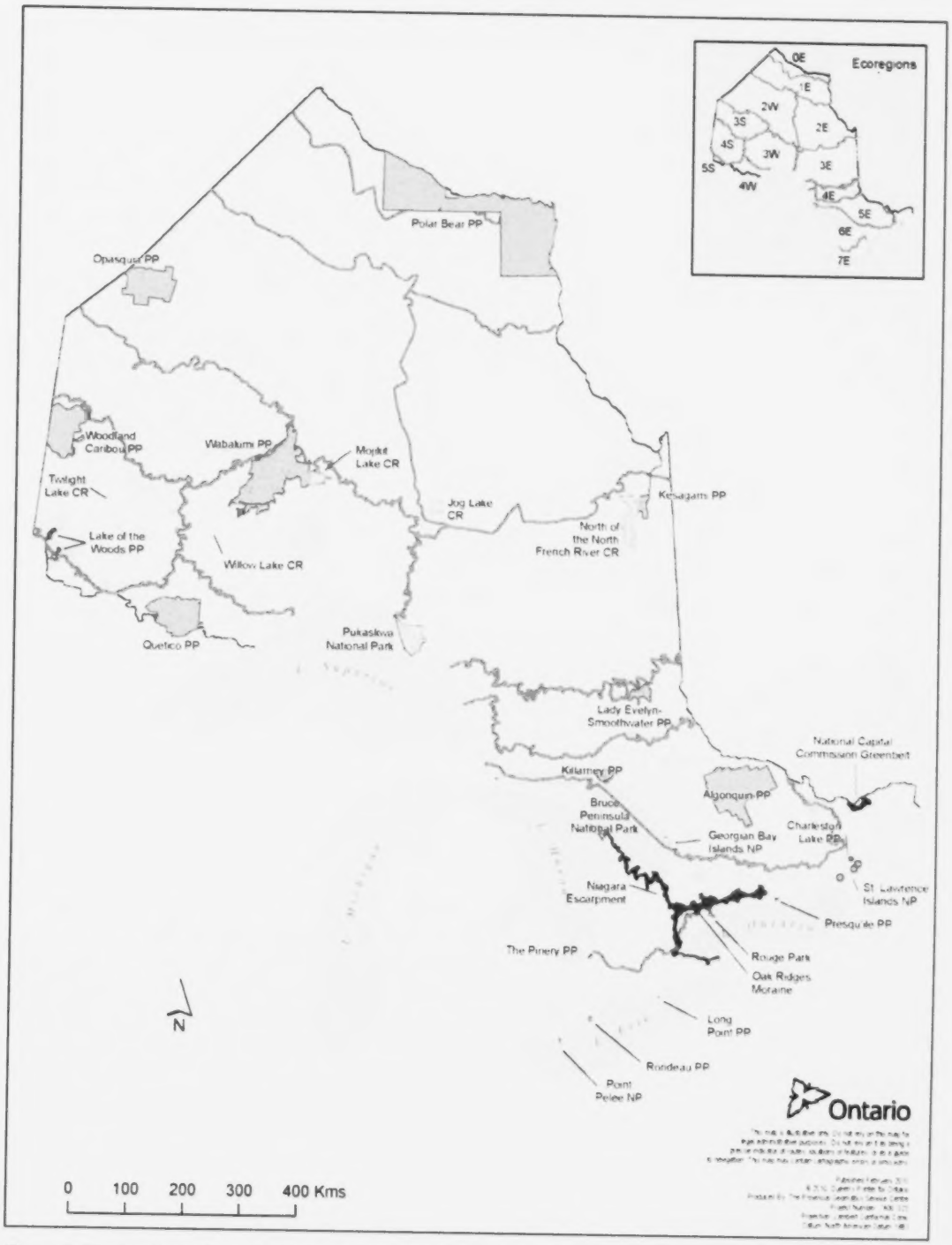

Figure 2. *The locations of natural heritage areas selected for this study.*

Methods

Describing Ontario's Current Climate

The climate data used in this study are part of a larger effort to produce spatial climate models for all of North America (e.g., see McKenney et al. 2007a for details). Here we used standard 30-year mean monthly values (or "normals") of minimum and maximum temperature and total precipitation for the 1971-2000 period (McKenney et al. 2006a). The climate models were generated using the thin plate smoothing spline algorithms of ANUSPLIN (Hutchinson 2001). ANUSPLIN uses climate station data to produce spatially continuous models (see Wahba 1990 for details on thin plate smoothing splines). The models of current climate developed for this study had relatively high levels of accuracy, with error levels of about half a degree Celsius for temperature variables and 10 to 20% for precipitation (McKenney et al. 2006a) and fall within the range of measurement error.

From these basic climate variables, nineteen bioclimatic variables were derived using ANUCLIM (Nix 1986, Houlder et al. 2000; Table 1). Between the monthly temperature and precipitation estimates and subsequently derived bioclimatic variables, a total of 55 climate variables were available to use in characterizing the climate of the ecoregions. Given that the size and shape of maps of the climate envelope for each ecoregion will vary depending on the climate variables included in the analysis (Beaumont et al. 2005), selection of appropriate variables is important. When generating climate envelopes for ecoregions and tree species, we selected variables that summarized two important climatic gradients for plants – heat and moisture (Woodward 1987). For heat, we used annual mean temperature (AMT), minimum temperature of the coldest month (MINT), and maximum temperature of the warmest month (MAXT). These variables

Table 1. *Bioclimatic variables derived from primary climate surfaces.*

No.	Variable	Description
1	Annual mean temperature	Avg. of mean monthly temperatures
2	Mean diurnal range	Avg. of monthly temperature ranges
3	Isothermality	No. 2 ÷ No.7
4	Temperature seasonality	Standard deviation of monthly mean temperature estimates expressed as a % of their mean
5	Max. temperature of warmest period	The highest the monthly maximum temperature
6	Min. temperature of coldest period	The lowest monthly minimum temperature
7	Temperature annual range	No. 5 – No. 6
8	Mean temperature of wettest quarter	Avg. temperature during 3 wettest months
9	Mean temperature of driest quarter	Avg. temperature during 3 driest months
10	Mean temperature of warmest quarter	Avg. temperature during 3 warmest months
11	Mean temperature of coldest quarter	Avg. temperature during 3 coldest months
12	Annual precipitation	Sum of monthly precipitation values
13	Precipitation of wettest period	Precipitation of the wettest month
14	Precipitation of driest period	Precipitation of the driest month
15	Precipitation seasonality	Standard deviation of the monthly precipitation estimates expressed as a % of their mean
16	Precipitation of wettest quarter	Total precipitation of 3 wettest months
17	Precipitation of driest quarter	Total precipitation of 3 driest months
18	Precipitation of warmest quarter	Total precipitation of 3 warmest months
19	Precipitation of coldest quarter	Total precipitation of 3 coldest months

represent the mean and extreme values of temperature at a given location and are highly correlated ($r > 0.90$) with other familiar climatic controls on plant distribution, such as extreme minimum temperature, growing season length, and degree days. Moisture gradients were similarly summarized using annual precipitation (ANNP), precipitation in the warmest quarter (PRECWQ), and precipitation in the coldest quarter (PRECCQ). To summarize the current and future climate for selected natural heritage areas, we report these six variables as well as eight others of general interest: mean diurnal range, annual temperature range, growing season start date, growing season end date, growing season length, growing season degree days, growing season mean temperature, and growing season temperature range.

Describing Ontario's Potential Future Climates

Projections of monthly temperature and precipitation were generated for each year over the period 2011-2100. The projections were based on the outputs from 2 emission scenarios for the following GCMs: (1) the Canadian GCM (CGCM2; Boer et al. 2000), (2) the UK-based Hadley GCM (HadCM3; Gordon et al. 2000), (3) the Australian-based Commonwealth Scientific and Industrial Research Organisation GCM (CSIRO; Gordon and O'Farrell 1997), and (4) the US-based National Center for Atmospheric Research GCM (NCAR; Collins et al. 2006). Data were obtained for the A2 and B2 emissions scenarios (see Nakicenovic and Swart 2000). They differ in that scenario A2 assumes a higher human population, less-forested land, greater pollution, and higher carbon dioxide (CO_2) emissions. Scenario B2 assumes an acceleration of energy and resource conservation efforts during the early decades of this century, such that CO_2 emissions will decline by mid-century. These scenarios were selected to assess plausible futures, given a range in human choices over the next few decades. For the CGCM2 output, the data were downloaded from the Canadian Centre for Climate Modelling and Analysis (http://www.cccma.bc.ec.gc.ca/data/cgcm2/cgcm2.shtml); for all other models, data were obtained from the IPCC data distribution centre (http://ipccddc.cru.uea.ac.uk).

GCM outputs are typically provided at very coarse spatial scales (e.g., 200 x 300 km grid cells), so it was necessary to interpolate them for use in regional applications (see McKenney et al. 2006b and Colombo et al. 2007 for details). First, annual change estimates were calculated between GCM outputs and a reference period (i.e., 1961-1990) for each climate variable at each GCM output location. These annual change estimates were then averaged for 3 time periods (2011-2040, 2041-2070, and 2071-2100). A model was generated for each period by interpolating the coarse-scale average change values. These change surfaces were then "resolved" at the location of climate stations across the both the United States and Canada with the predicted changes at each location being combined with the 1971-2000 average values. This provided a network of station values that included both current climate and the changes projected by the GCMs. This method of adding the model-generated anomalies to current climate values also has the advantage of eliminating bias in the control run of the GCM model (Overpeck et al. 1991). Derived bioclimatic variables were generated as outlined above. Using 30-year averages rather than single year values for the future values reduced the risk of using GCM output from an anomalous year.

Generating Climate Envelopes for Ecoregions, Natural Heritage Areas, and Tree Species

The current and future surfaces for the climate variables of interest were mapped at a resolution of 300 arc seconds (approximately a 10 km grid). For the ecoregion aspect of the work, these grids were overlain with the ecoregion polygons and climatic summaries were generated for each ecoregion using ANUCLIM (Nix 1986, Houlder et al. 2000). The ANUCLIM summaries identify a climate envelope for each ecoregion (i.e., maximum and minimum values for numerous climate variables) as well as a "core range" that identifies

the values associated with the 5th and 95th percentile for each climate variable. The idea of the core range is to identify a smaller climate envelope that better represents the central climatic conditions of each ecoregion. These summaries were used in two ways. First, the location of the current climatic conditions in each ecoregion was mapped for each future time period, indicating where that ecoregion's climate is predicted to migrate during this century. Second, the climatic conditions in each ecoregion were summarized for each 30-year period to show how climate is projected to change within the currently defined ecoregion boundaries.

For the natural heritage areas component, we identified 12 tree species with a range of climatic and site type preferences (Table 2) and 29 natural heritage areas from across the province (Table 3). The selected natural heritage areas include National Parks, Provincial Parks, Conservation Reserves, Rouge Park, National Capital Commission Lands, the Oak Ridges Moraine, and the Niagara Escarpment. The selection criteria, management objectives, legislation, and operating principles of these and many other types of natural heritage areas are described in Gray et al. (2009). Current climate envelopes (both the full and core ranges as described above) were generated for each tree species using plant occurrence data from a plant hardiness data set (see McKenney et al. 2007b for description of the plant hardiness project and McKenney et al. 2007c for details of tree distribution and climate change study) and the six climate variables outlined above. These climatic conditions were then located on maps of expected future climate to track the movement of the climate envelope for each tree species in each of the 30-year periods. For each time period, the amount of climate habitat contained within the natural heritage network was summarized for each tree species. The presence or absence of climate habitat for each tree species in each of the 29 natural heritage areas was also tracked for each time period. Finally, the current and future climate for each of the selected natural heritage areas was summarized for the 14 climate variables outlined above.

Table 2. *Tree species considered in this study.*

Common Name	Scientific Name
Black spruce	*Picea mariana* (Mill.) B.S.P.
White spruce	*Picea glauca* (Moench) Voss
Jack pine	*Pinus banksiana* Lamb.
Balsam fir	*Abies balsamea* (L.) Mill.
Trembling aspen	*Populus tremuloides* Michx.
White pine	*Pinus strobus* L.
Red pine	*Pinus resinosa* Aiton
Sugar maple	*Acer saccharum* Marshall
Red oak	*Quercus rubra* L.
Tulip poplar	*Liriodendron tulipifera* L.
Black walnut	*Juglans nigra* L.
Shagbark hickory	*Carya ovata* (Mill.) K.Koch

Table 3. *Natural heritage areas included in this study.*

Park	Ecoregion	Park	Ecoregion
Oak Ridges Moraine	6E	Polar Bear Provincial Park	0E/1E
Rouge Park	6E	Point Pelee National Park	7E
Niagara Escarpment	6E/7E	Opasquia Provincial Park	2W
Mojikit Lake Conservation Reserve	3W	North French River Conservation Reserve	3E
Wabakimi Provincial Park	3W	National Capital Commission	6E
Woodland Caribou Provincial Park	4S	Long Point Provincial Park	7E
Willow Lake Conservation Reserve	3S	Lake of the Woods Provincial Park	4S
Twilight Lake Conservation Reserve	3S	Lady Evelyn-Smoothwater Provincial Park	4E
The Pinery Provincial Park	7E	Killarney Provincial Park	5E
St. Lawrence Islands National Park	6E	Kesagami Provincial Park	3E
Rondeau Provincial Park	7E	Jog Lake Conservation Reserve	2E
Quetico Provincial Park	4W	Georgian Bay Islands National Park	5E
Pukaskwa National Park	3E	Charleston Lake Provincial Park	6E
Presqu'ile Provincial Park	6E	Bruce Peninsula National Park	6E
		Algonquin Provincial Park	5E

Results

Climate Change in Ontario

A general sense of the changes in climate projected for Ontario's ecoregions can be obtained by examining maps of climate for each time period. Such projections are shown here for the CGCM2 A2 scenario for annual mean temperature (Figure 3) and annual precipitation (Figure 4). Similar patterns are evident in outputs from all GCMs, but the magnitude of the changes varies with the greenhouse gas emissions scenario used. For more detailed Ontario maps, see Colombo et al. (2007); a full suite of maps for North America is also available at http://cfs.nrcan.gc.ca/subsite/glfc-climate/climate.

As the century progresses, a northward shift in average temperature is clearly visible (Figure 3). However, patterns of precipitation change are less clear – in many locations precipitation remains relatively constant (Figure 4).

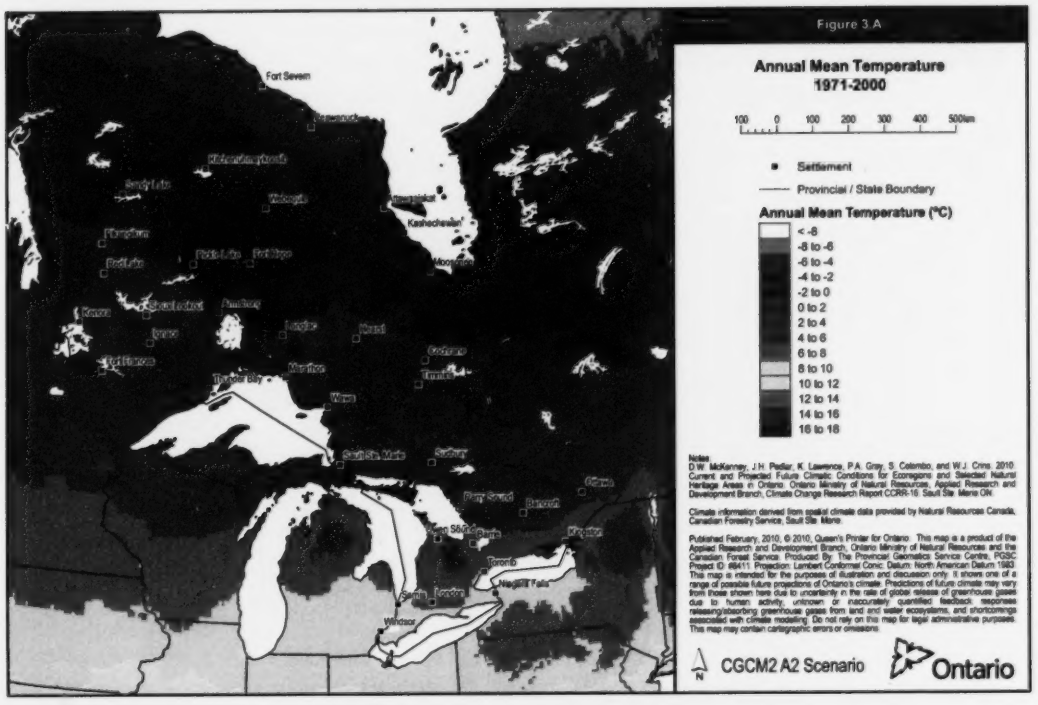
Figure 3.A
Annual Mean Temperature
1971-2000
100 0 100 200 300 400 500km
Settlement
Provincial / State Boundary
Annual Mean Temperature (°C)
< -8
-8 to -6
-6 to -4
-4 to -2
-2 to 0
0 to 2
2 to 4
4 to 6
6 to 8
8 to 10
10 to 12
12 to 14
14 to 16
16 to 18
Notes
D.W. McKenney, J.H. Pedlar, K. Lawrence, P.A. Gray, S. Colombo, and W.J. Crins. 2010. Current and Projected Future Climatic Conditions for Ecoregions and Selected Natural Heritage Areas in Ontario. Ontario Ministry of Natural Resources, Applied Research and Development Branch, Climate Change Research Report CCRR-16. Sault Ste. Marie ON.
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CGCM2 A2 Scenario
Ontario
Fort Severn
Kashechewan
Moosonee
Kenora
Fort Frances
Thunder Bay
Marathon
Wawa
Sault Ste. Marie
Sudbury
Timmins
Parry Sound
Barrie
Kingston
Toronto
Niagara Falls
Sarnia
London
Windsor

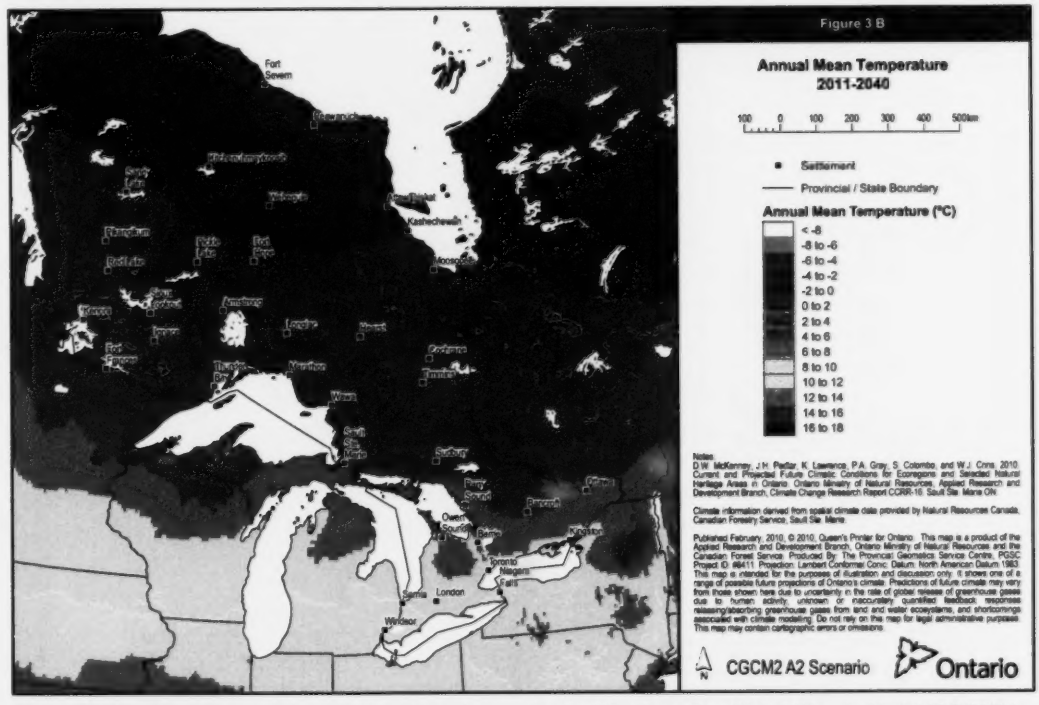
Figure 3.B
Annual Mean Temperature
2011-2040
100 0 100 200 300 400 500km
Settlement
Provincial / State Boundary
Annual Mean Temperature (°C)
< -8
-8 to -6
-6 to -4
-4 to -2
-2 to 0
0 to 2
2 to 4
4 to 6
6 to 8
8 to 10
10 to 12
12 to 14
14 to 16
16 to 18
Notes
D.W. McKenney, J.H. Pedlar, K. Lawrence, P.A. Gray, S. Colombo, and W.J. Crins. 2010. Current and Projected Future Climatic Conditions for Ecoregions and Selected Natural Heritage Areas in Ontario. Ontario Ministry of Natural Resources, Applied Research and Development Branch, Climate Change Research Report CCRR-16. Sault Ste. Marie ON.
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CGCM2 A2 Scenario
Ontario
Fort Severn
Kashechewan
Moosonee
Kenora
Fort Frances
Thunder Bay
Marathon
Wawa
Sault Ste. Marie
Sudbury
Timmins
Parry Sound
Barrie
Owen Sound
Kingston
Toronto
Niagara Falls
Sarnia
London
Windsor

Figure 3. *Annual mean temperature projections using version 2 of the Canadian Global Climate Model (CGCM2) with the A2 scenario across Ontario ecoregions for four time periods: (a) 1971-2000, (b) 2011-2040, (c) 2041-2070, and (d) 2071-2100.*

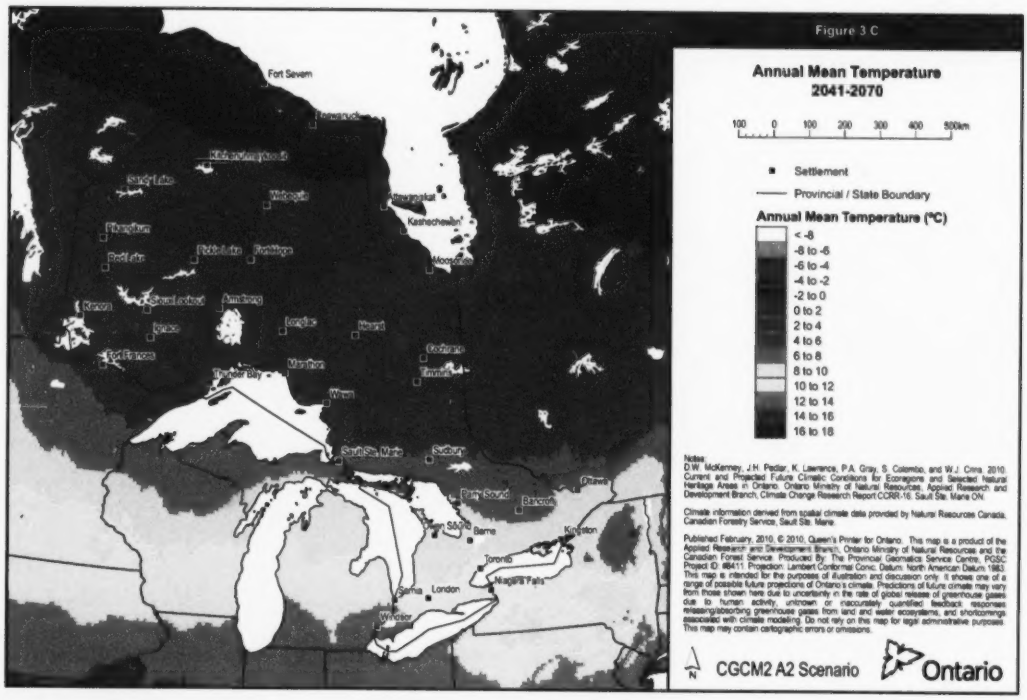
Figure 3.C
Annual Mean Temperature
2041-2070
100 0 100 200 300 400 500km
Settlement
Provincial / State Boundary
Annual Mean Temperature (°C)
< -8
-8 to -6
-6 to -4
-4 to -2
-2 to 0
0 to 2
2 to 4
4 to 6
6 to 8
8 to 10
10 to 12
12 to 14
14 to 16
16 to 18
Notes:
D.W. McKenney, J.H. Pedlar, K. Lawrence, P.A. Gray, S. Colombo, and W.J. Crins. 2010. Current and Projected Future Climatic Conditions for Ecoregions and Selected Natural Heritage Areas in Ontario. Ontario Ministry of Natural Resources, Applied Research and Development Branch, Climate Change Research Report CCRR-16. Sault Ste. Marie ON.
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CGCM2 A2 Scenario
Ontario
Fort Severn
Sioux Lookout
Kashechewan
Moosonee
Timmins
Thunder Bay
Sault Ste. Marie
Sudbury
Parry Sound
Bancroft
Ottawa
Barrie
Kingston
Toronto
Niagara Falls
Sarnia
London
Windsor

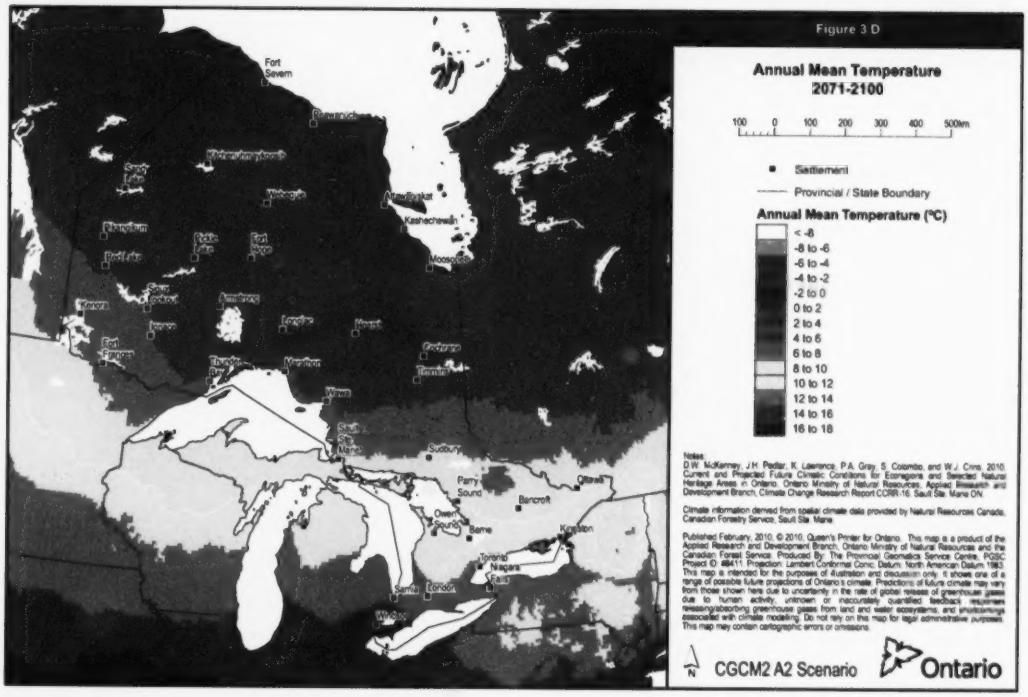
Figure 3.D
Annual Mean Temperature
2071-2100
100 0 100 200 300 400 500km
Settlement
Provincial / State Boundary
Annual Mean Temperature (°C)
< -8
-8 to -6
-6 to -4
-4 to -2
-2 to 0
0 to 2
2 to 4
4 to 6
6 to 8
8 to 10
10 to 12
12 to 14
14 to 16
16 to 18
Notes:
D.W. McKenney, J.H. Pedlar, K. Lawrence, P.A. Gray, S. Colombo, and W.J. Crins. 2010. Current and Projected Future Climatic Conditions for Ecoregions and Selected Natural Heritage Areas in Ontario. Ontario Ministry of Natural Resources, Applied Research and Development Branch, Climate Change Research Report CCRR-16. Sault Ste. Marie ON.
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CGCM2 A2 Scenario
Ontario
Fort Severn
Sioux Lookout
Kashechewan
Moosonee
Timmins
Thunder Bay
Sault Ste. Marie
Sudbury
Parry Sound
Bancroft
Ottawa
Barrie
Kingston
Toronto
Niagara Falls
Sarnia
London
Windsor

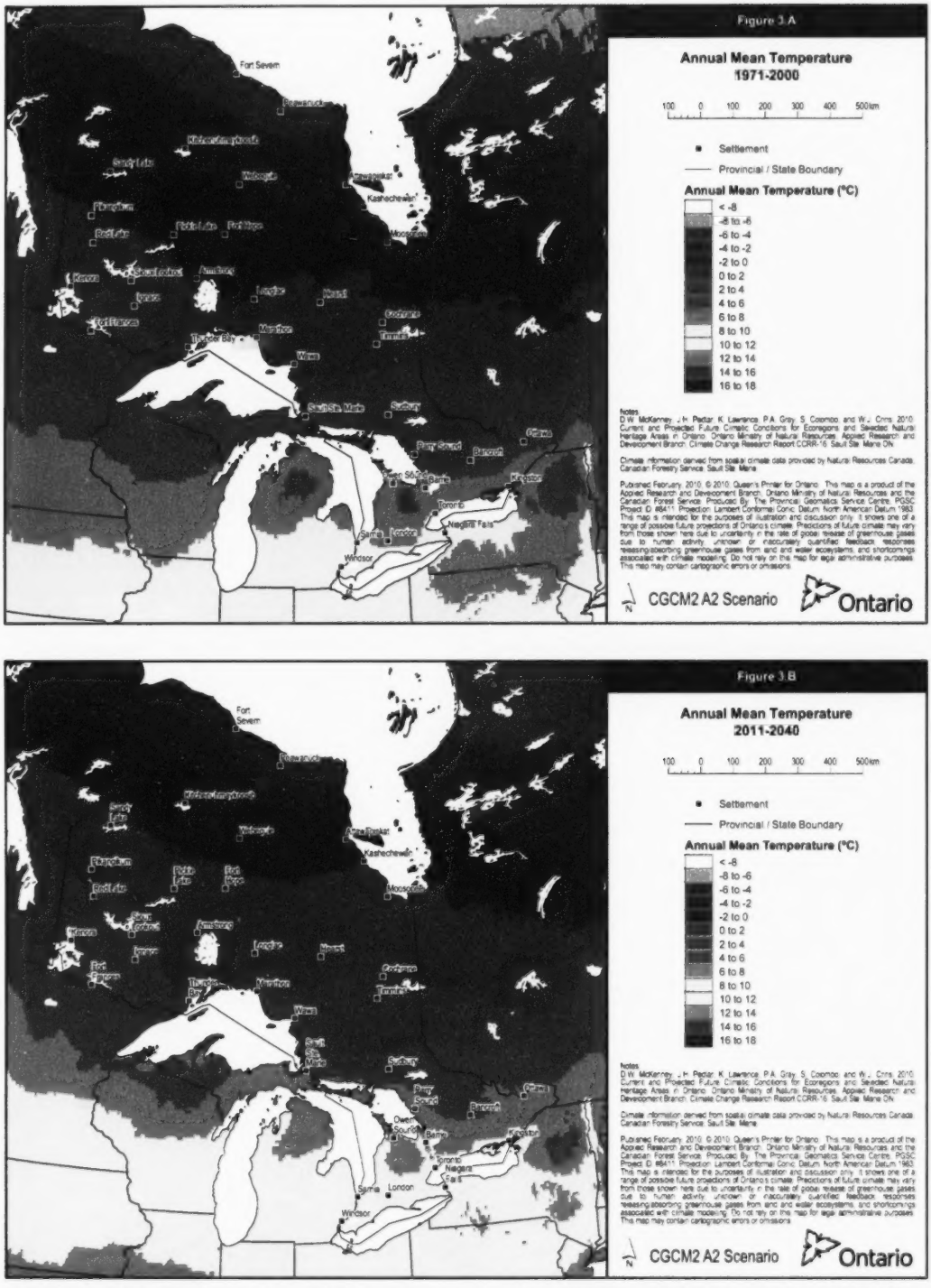

Figure 3. *Annual mean temperature projections using version 2 of the Canadian Global Climate Model (CGCM2) with the A2 scenario across Ontario ecoregions for four time periods: (a) 1971-2000, (b) 2011-2040, (c) 2041-2070, and (d) 2071-2100.*

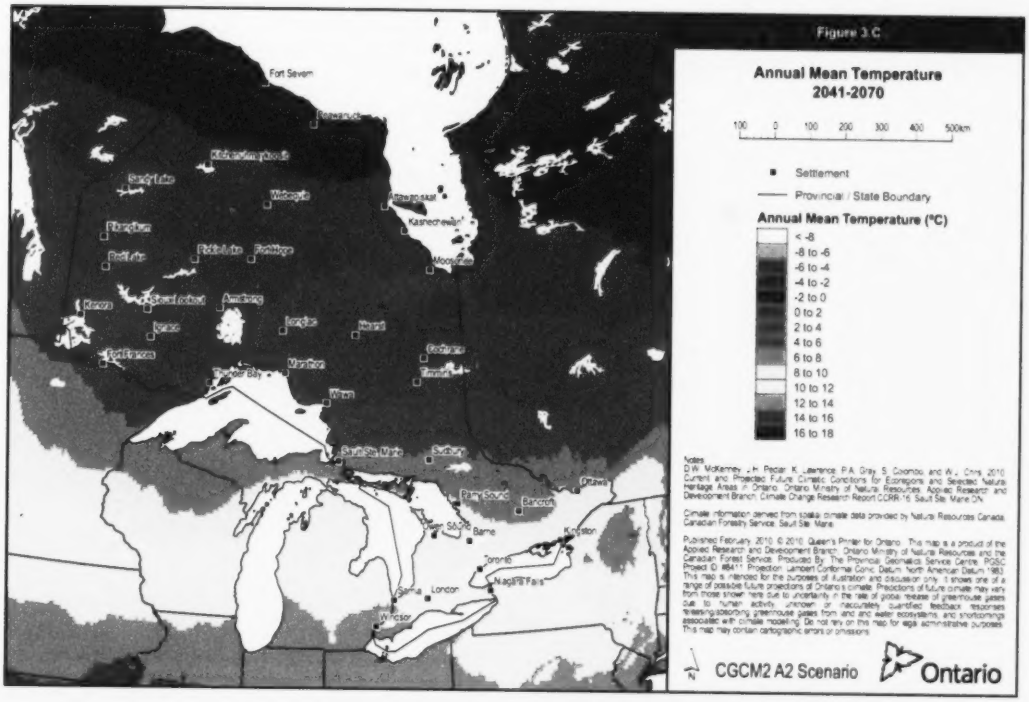
Figure 3.C
Annual Mean Temperature
2041-2070
100 0 100 200 300 400 500km
Settlement
Provincial / State Boundary
Annual Mean Temperature (°C)
< -8
-8 to -6
-6 to -4
-4 to -2
-2 to 0
0 to 2
2 to 4
4 to 6
6 to 8
8 to 10
10 to 12
12 to 14
14 to 16
16 to 18
Fort Severn
Sioux Lookout
Kasabonika
Kashechewan
Moosonee
Fort Albany
Attawapiskat
Peawanuck
Pickle Lake
Fort Hope
Red Lake
Ear Falls
Sandy Lake
Wapekeka
Keewaywin
Poplar Hill
Deer Lake
Pikangikum
Kenora
Sioux Lookout
Ignace
Dryden
Fort Frances
Atikokan
Thunder Bay
Nipigon
Geraldton
Longlac
Marathon
Wawa
Sault Ste. Marie
Sudbury
Parry Sound
Bancroft
Ottawa
Barrie
Kingston
Toronto
Niagara Falls
Sarnia
London
Windsor
CGCM2 A2 Scenario
Ontario

Figure 3.D
Annual Mean Temperature
2071-2100
100 0 100 200 300 400 500km
Settlement
Provincial / State Boundary
Annual Mean Temperature (°C)
< -8
-8 to -6
-6 to -4
-4 to -2
-2 to 0
0 to 2
2 to 4
4 to 6
6 to 8
8 to 10
10 to 12
12 to 14
14 to 16
16 to 18
Fort Severn
Sioux Lookout
Kasabonika
Kashechewan
Moosonee
Fort Albany
Attawapiskat
Peawanuck
Pickle Lake
Fort Hope
Red Lake
Ear Falls
Sandy Lake
Wapekeka
Keewaywin
Poplar Hill
Deer Lake
Pikangikum
Kenora
Sioux Lookout
Ignace
Dryden
Fort Frances
Atikokan
Thunder Bay
Nipigon
Geraldton
Longlac
Marathon
Wawa
Sault Ste. Marie
Sudbury
Parry Sound
Bancroft
Ottawa
Barrie
Kingston
Toronto
Niagara Falls
Sarnia
London
Windsor
CGCM2 A2 Scenario
Ontario

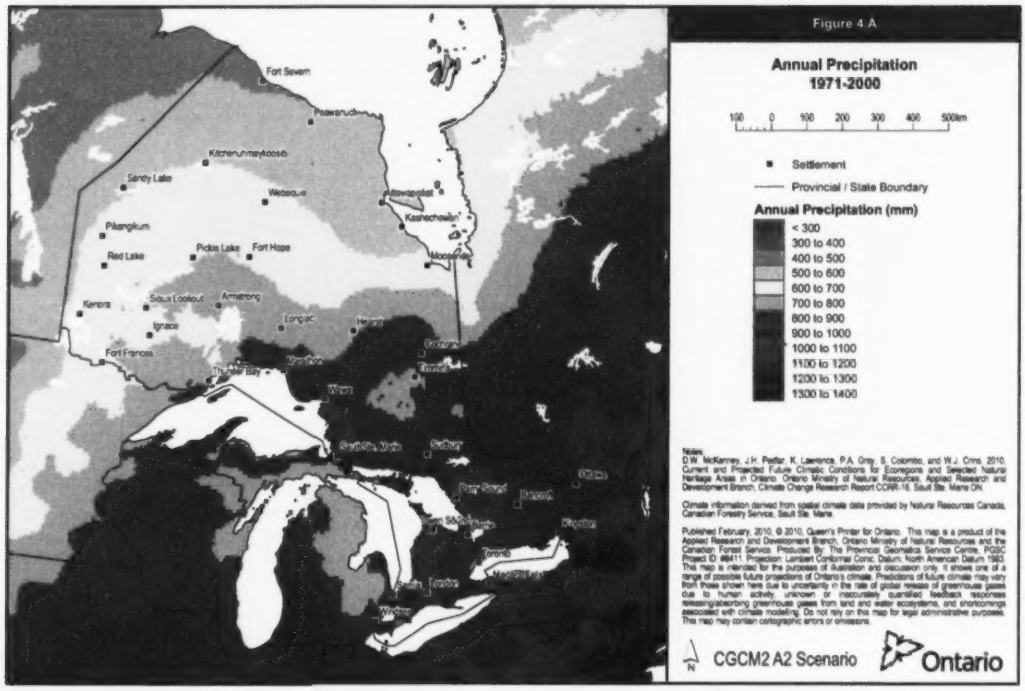
Figure 4.A
Annual Precipitation
1971-2000
100 0 100 200 300 400 500km
Settlement
Provincial / State Boundary
Annual Precipitation (mm)
< 300
300 to 400
400 to 500
500 to 600
600 to 700
700 to 800
800 to 900
900 to 1000
1000 to 1100
1100 to 1200
1200 to 1300
1300 to 1400
Notes
D.W. McKenney, J.H. Pedlar, K. Lawrence, P.A. Gray, S. Colombo, and W.J. Crins. 2010. Current and Projected Future Climatic Conditions for Ecoregions and Selected Natural Heritage Areas in Ontario. Ontario Ministry of Natural Resources. Applied Research and Development Branch, Climate Change Research Report CCRR-16. Sault Ste. Marie ON.
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CGCM2 A2 Scenario
Ontario
Fort Severn
Peawanuck
Kitchenuhmaykoosib
Sandy Lake
Webequie
Attawapiskat
Kashechewan
Moosonee
Pikangikum
Red Lake
Pickle Lake
Fort Hope
Kenora
Sioux Lookout
Armstrong
Longlac
Hearst
Ignace
Fort Frances
Thunder Bay
Wawa
Sudbury
Timmins
Kirkland Lake
Parry Sound
Bracebridge
Muskoka
Toronto
Niagara Falls
Windsor

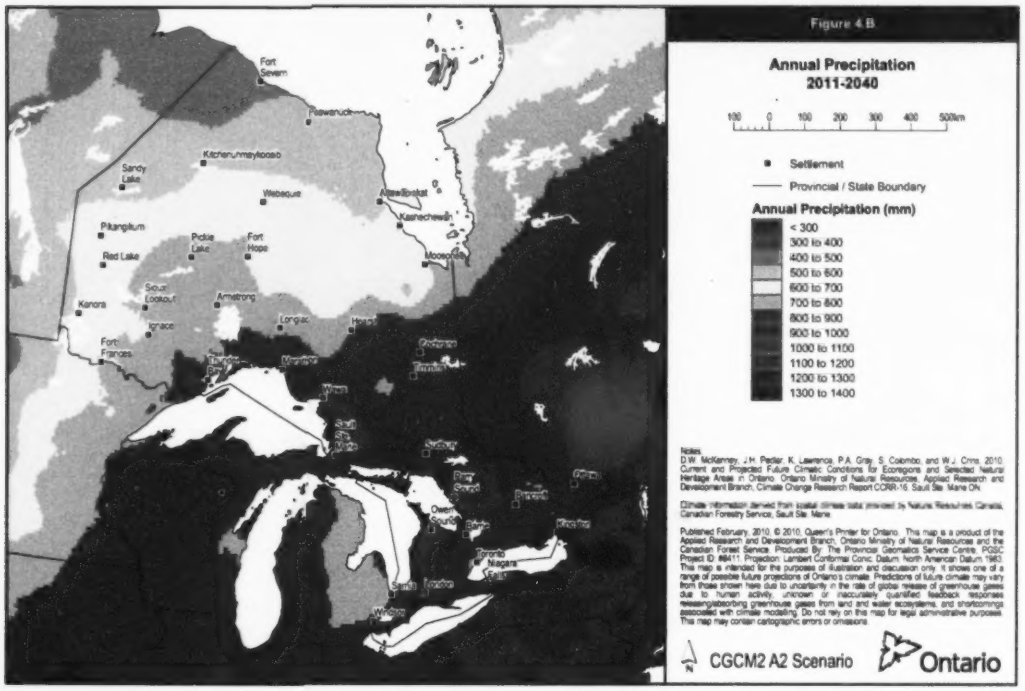
Figure 4.B
Annual Precipitation
2011-2040
100 0 100 200 300 400 500km
Settlement
Provincial / State Boundary
Annual Precipitation (mm)
< 300
300 to 400
400 to 500
500 to 600
600 to 700
700 to 800
800 to 900
900 to 1000
1000 to 1100
1100 to 1200
1200 to 1300
1300 to 1400
Notes
D.W. McKenney, J.H. Pedlar, K. Lawrence, P.A. Gray, S. Colombo, and W.J. Crins. 2010. Current and Projected Future Climatic Conditions for Ecoregions and Selected Natural Heritage Areas in Ontario. Ontario Ministry of Natural Resources. Applied Research and Development Branch, Climate Change Research Report CCRR-16. Sault Ste. Marie ON.
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CGCM2 A2 Scenario
Ontario
Fort Severn
Peawanuck
Kitchenuhmaykoosib
Sandy Lake
Webequie
Attawapiskat
Kashechewan
Moosonee
Pikangikum
Red Lake
Pickle Lake
Fort Hope
Kenora
Sioux Lookout
Armstrong
Longlac
Hearst
Ignace
Fort Frances
Thunder Bay
Wawa
Sudbury
Timmins
Kirkland Lake
Parry Sound
Bracebridge
Muskoka
Toronto
Niagara Falls
Windsor

Figure 4. *Annual precipitation projections using version 2 of the Canadian Global Climate Model (CGCM2) with the A2 scenario across Ontario ecoregions for four time periods: (a) 1971-2000, (b) 2011-2040, (c) 2041-2070, and (d) 2071-2100*

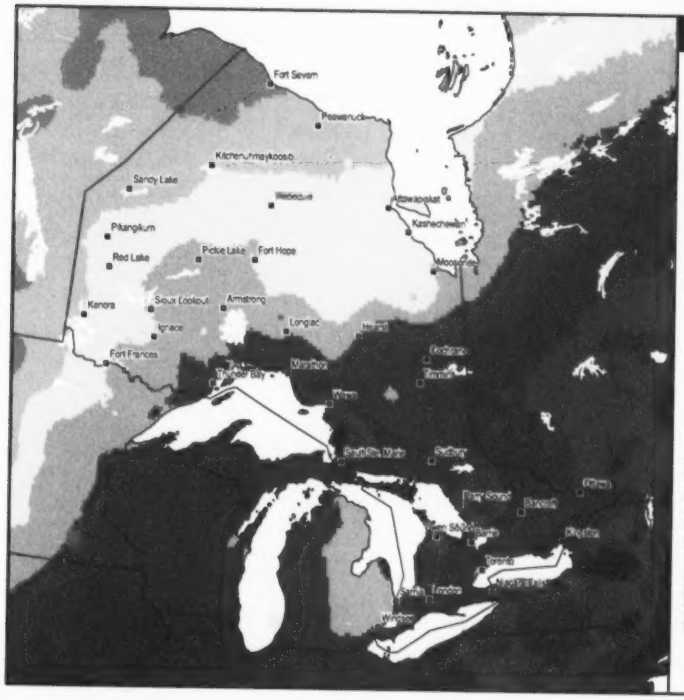

Figure 4.C

Annual Precipitation 2041-2070

100 0 100 200 300 400 500km

Settlement

Provincial / State Boundary

Annual Precipitation (mm)

- < 300
- 300 to 400
- 400 to 500
- 500 to 600
- 600 to 700
- 700 to 800
- 800 to 900
- 900 to 1000
- 1000 to 1100
- 1100 to 1200
- 1200 to 1300
- 1300 to 1400

Notes:
D.W. McKenney, J.H. Pedlar, K. Lawrence, P.A. Gray, S. Colombo, and W.J. Crins. 2010. Current and Projected Future Climatic Conditions for Ecoregions and Selected Natural Heritage Areas in Ontario. Ontario Ministry of Natural Resources, Applied Research and Development Branch, Climate Change Research Report CCRR-16. Sault Ste. Marie ON.

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N

CGCM2 A2 Scenario

Ontario

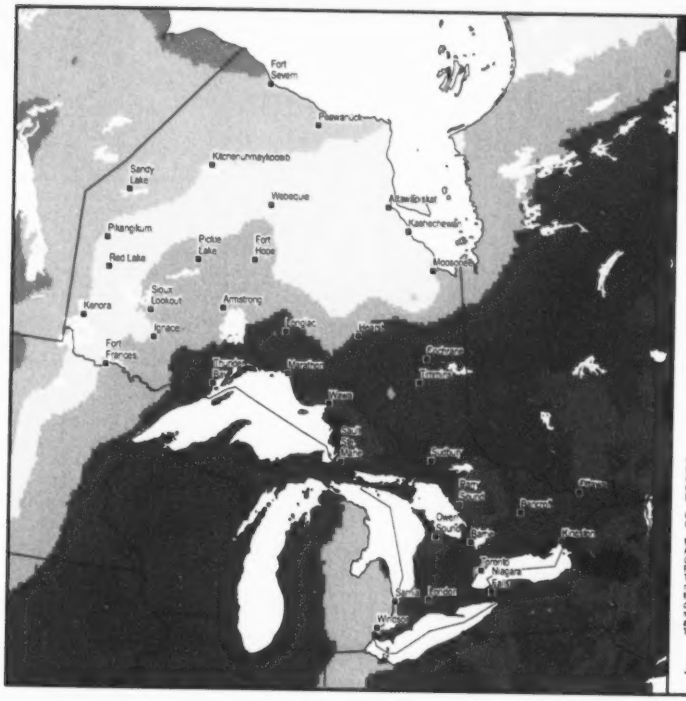

Figure 4.D

Annual Precipitation 2071-2100

100 0 100 200 300 400 500km

Settlement

Provincial / State Boundary

Annual Precipitation (mm)

- < 300
- 300 to 400
- 400 to 500
- 500 to 600
- 600 to 700
- 700 to 800
- 800 to 900
- 900 to 1000
- 1000 to 1100
- 1100 to 1200
- 1200 to 1300
- 1300 to 1400

Notes:
D.W. McKenney, J.H. Pedlar, K. Lawrence, P.A. Gray, S. Colombo, and W.J. Crins. 2010. Current and Projected Future Climatic Conditions for Ecoregions and Selected Natural Heritage Areas in Ontario. Ontario Ministry of Natural Resources, Applied Research and Development Branch, Climate Change Research Report CCRR-16. Sault Ste. Marie ON.

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N

CGCM2 A2 Scenario

Ontario

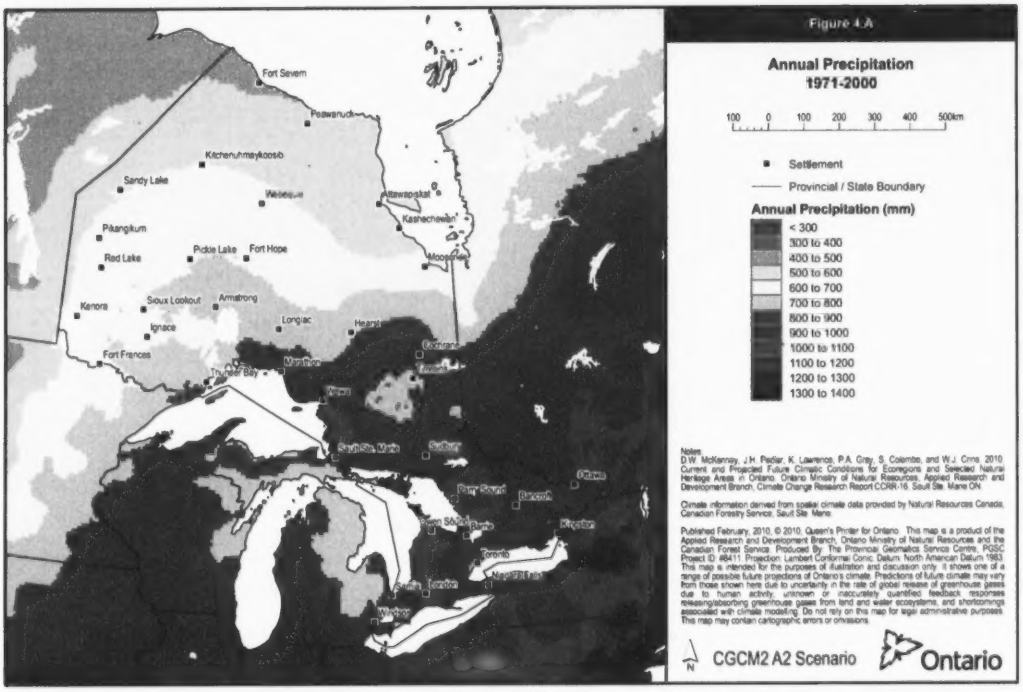
Figure 4.A
Annual Precipitation
1971-2000
100 0 100 200 300 400 500km
Settlement
Provincial / State Boundary
Annual Precipitation (mm)
< 300
300 to 400
400 to 500
500 to 600
600 to 700
700 to 800
800 to 900
900 to 1000
1000 to 1100
1100 to 1200
1200 to 1300
1300 to 1400
Notes
D.W. McKenney, J.H. Pedlar, K. Lawrence, P.A. Gray, S. Colombo, and W.J. Crins. 2010. Current and Projected Future Climatic Conditions for Ecoregions and Selected Natural Heritage Areas in Ontario. Ontario Ministry of Natural Resources, Applied Research and Development Branch, Climate Change Research Report CCRR-16. Sault Ste. Marie ON.
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CGCM2 A2 Scenario
Ontario
Fort Severn
Peawanuck
Kitchenuhmaykoosib
Sandy Lake
Webequie
Attawapiskat
Kashechewan
Pikangikum
Red Lake
Pickle Lake
Fort Hope
Moosonee
Kenora
Sioux Lookout
Armstrong
Ignace
Longlac
Hearst
Fort Frances
Thunder Bay
Marathon
Timmins
Wawa
Sault Ste. Marie
Sudbury
Parry Sound
Ottawa
Pembroke
Kingston
Owen Sound
Toronto
Niagara Falls
London
Sarnia
Windsor

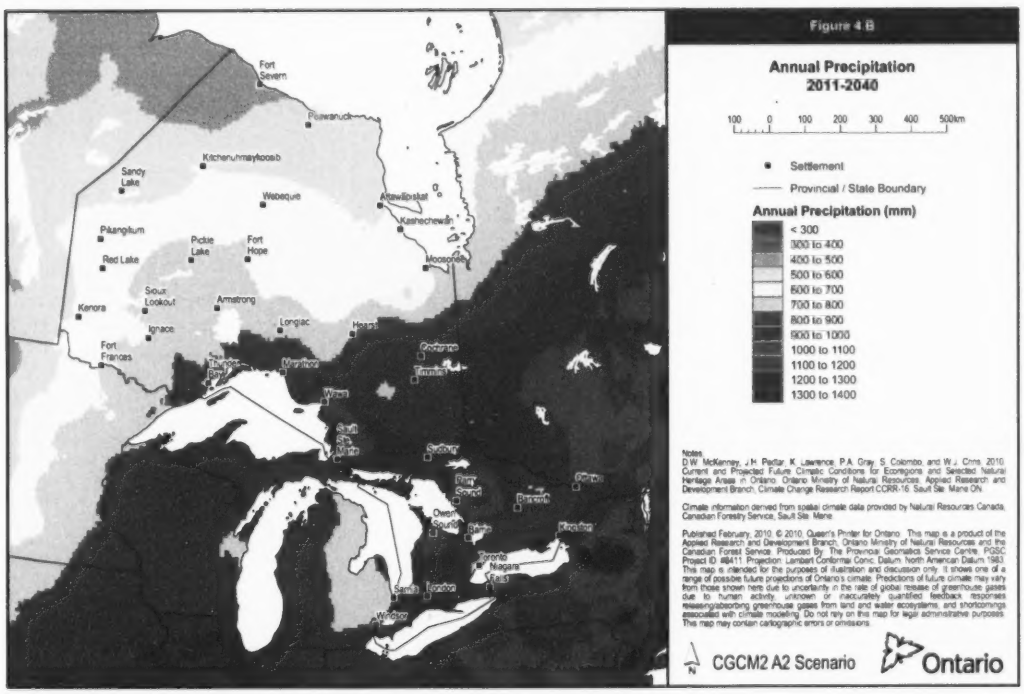
Figure 4.B
Annual Precipitation
2011-2040
100 0 100 200 300 400 500km
Settlement
Provincial / State Boundary
Annual Precipitation (mm)
< 300
300 to 400
400 to 500
500 to 600
600 to 700
700 to 800
800 to 900
900 to 1000
1000 to 1100
1100 to 1200
1200 to 1300
1300 to 1400
Notes
D.W. McKenney, J.H. Pedlar, K. Lawrence, P.A. Gray, S. Colombo, and W.J. Crins. 2010. Current and Projected Future Climatic Conditions for Ecoregions and Selected Natural Heritage Areas in Ontario. Ontario Ministry of Natural Resources, Applied Research and Development Branch, Climate Change Research Report CCRR-16. Sault Ste. Marie ON.
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CGCM2 A2 Scenario
Ontario
Fort Severn
Peawanuck
Kitchenuhmaykoosib
Sandy Lake
Webequie
Attawapiskat
Kashechewan
Pikangikum
Red Lake
Pickle Lake
Fort Hope
Moosonee
Kenora
Sioux Lookout
Armstrong
Ignace
Longlac
Hearst
Fort Frances
Thunder Bay
Marathon
Timmins
Wawa
Sault Ste. Marie
Sudbury
Parry Sound
Ottawa
Pembroke
Kingston
Owen Sound
Toronto
Niagara Falls
London
Sarnia
Windsor

Figure 4. *Annual precipitation projections using version 2 of the Canadian Global Climate Model (CGCM2) with the A2 scenario across Ontario ecoregions for four time periods: (a) 1971-2000, (b) 2011-2040, (c) 2041-2070, and (d) 2071-2100*

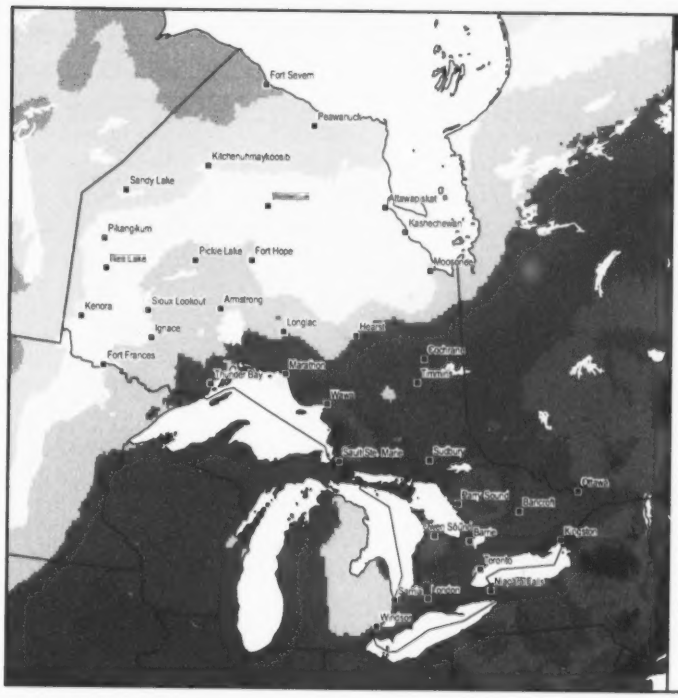

Figure 4.C

Annual Precipitation
2041-2070

100 0 100 200 300 400 500km

Settlement

Provincial / State Boundary

Annual Precipitation (mm)

- < 300
- 300 to 400
- 400 to 500
- 500 to 600
- 600 to 700
- 700 to 800
- 800 to 900
- 900 to 1000
- 1000 to 1100
- 1100 to 1200
- 1200 to 1300
- 1300 to 1400

Notes:
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N CGCM2 A2 Scenario Ontario

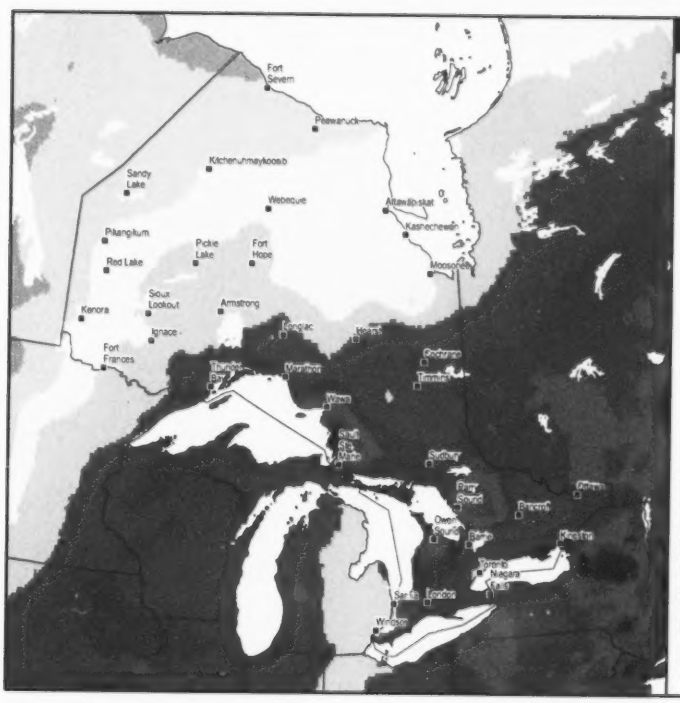

Figure 4.D

Annual Precipitation
2071-2100

100 0 100 200 300 400 500km

Settlement

Provincial / State Boundary

Annual Precipitation (mm)

- < 300
- 300 to 400
- 400 to 500
- 500 to 600
- 600 to 700
- 700 to 800
- 800 to 900
- 900 to 1000
- 1000 to 1100
- 1100 to 1200
- 1200 to 1300
- 1300 to 1400

Notes:
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N CGCM2 A2 Scenario Ontario

Climate Change and Ecoregions

A detailed summary of projected climate in each ecoregion is presented for emissions scenarios A2 (Appendix 1) and B2 (Appendix 2). The values presented here are averages of the outputs from all four GCMs. Based on the A2 emissions scenario, on average by the end of the century annual mean temperature across ecoregions is projected to change by 5.1°C; the highest change (5.9°C) is predicted for ecoregion 0E in the Far North, while the smallest change (4.8°C) is predicted for 5S in the far west. Patterns for the B2 scenario are essentially identical but on average the magnitude of the changes is about 1.5°C less. On average across the ecoregions, precipitation is projected to increase by 6.8% and 5.2% for the A2 and B2 scenarios respectively. For both scenarios, the largest change in precipitation (12%) is predicted for ecoregion 4E, while little or no change is predicted for ecoregion 5S. Note these changes are generally within current measurement errors at weather stations. It is the interactions between temperature, precipitation, soils, and timing of rainfall/snowfall events that are likely to be most critical for ecosystem composition, structure, and function. Although projected changes in precipitation are relatively small, reduced rainfall frequencies and the increased rates of evapotranspiration associated with higher temperatures will mean that the amount of soil moisture available to plants will likely be reduced in many locations.

A total of 448 maps (i.e., 14 ecoregions x 4 time periods x 4 GCMs x 2 emissions scenarios) were generated to show where the climate envelope for each ecoregion is projected to move over the course of the next century. Sample maps are provided here for ecoregions 3W (Figure 5) and 6E (Figure 6). The complete set of maps is provided on the CD accompanying this report.[1]

A common pattern across ecoregions was a slight northward shift in current climate conditions during the early part of this century followed by a more rapid shift predicted for the second half of the century. During 1971-2000, the climate in ecoregion 3W extended across most of north-central Ontario, covering about 240,000 km^2 in a band between approximately 48°N and 52°N and from northwestern Ontario to the Quebec border (Figure 5). Thirty to 60 years later, during 2041 to 2070, only two small areas in Ontario matched the climatic conditions of this ecoregion: an area of about 2400 km^2 north of Lake Superior and east of Lake Nipigon and a similar sized area south and east of Moosonee near James Bay. By 2071-2100 none of the core climate of ecoregion 3W is expected to occur in Ontario (Figure 5). Results were similar for all the northern ecoregions.

Ecoregion 6E covers most of the southern edge of the Great Lakes-St. Lawrence forest region in a band running from the Ottawa Valley in the east to Lake Huron in the west, including Manitoulin Island (Figure 6). Remnant forests in ecoregion 6E comprise predominantly tolerant hardwood stands of sugar maple (scientific names provided in Table 2 for selected species), yellow birch (*Betula alleghaniensis* Britton), and American beech (*Fagus grandifolia* Ehrh.), with lesser quantities of intolerant red oak stands, wetland cedar-spruce-tamarack, and occasional stands of conifers mixed with trembling aspen and white birch (*Betula papyrifera* Marsh.) on cooler sites. The current climate of this ecoregion is expected to shift northward in each time period. As early as 2011-2040, the only areas within the current ecoregions expected to retain this climate envelope are on Manitoulin Island and in southern Ontario between Owen Sound and Orangeville.

[1] Additional copies are available from Ontario Forest Research Institute, Ontario Ministry of Natural Resources, 1235 Queen Street East, Sault Ste. Marie, ON, P6A 2E5

Climate Change and Natural Heritage Areas

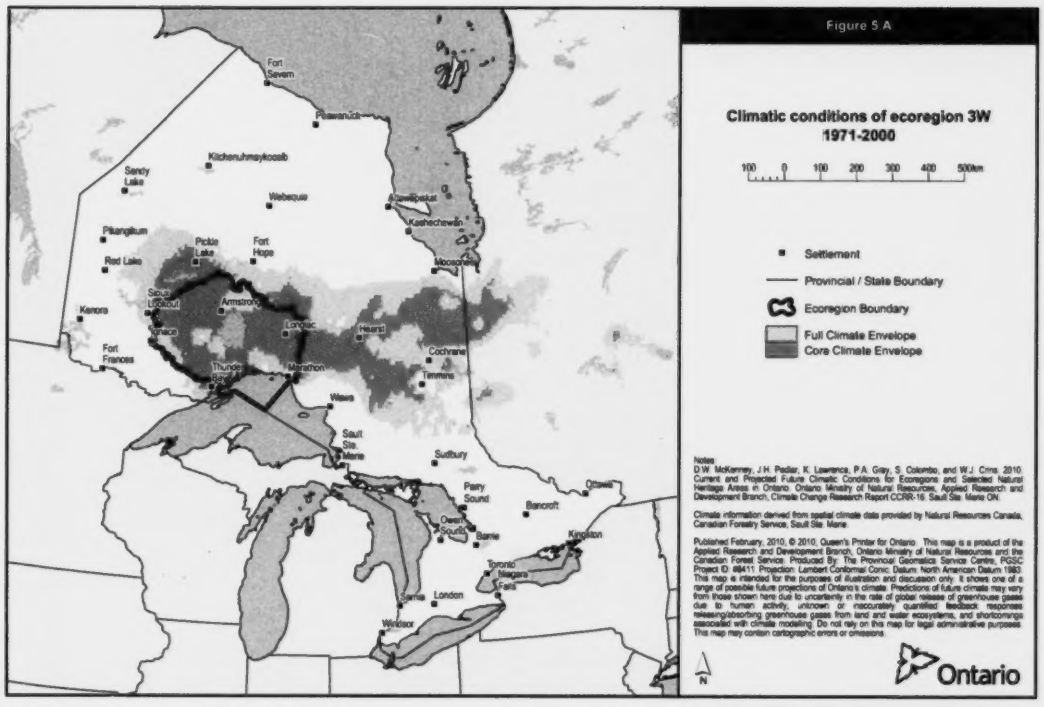
Current and future climatic profiles for Point Pelee National Park (Table 4), the Oak Ridges Moraine (Table 5), Algonquin Provincial Park (Table 6), and Polar Bear Provincial Park (Table 7) indicate substantial changes in many climate attributes. At the southern tip of the province, *average* daily maximum temperatures in July of more than 33°C by the end of the century are projected for Point Pelee National Park, similar to summer temperatures currently experienced in the state of Florida. At the other end of the province in Polar Bear Provincial Park, annual mean temperature is projected to increase from -4.5°C to nearly 2°C and the number of growing season degree days more than double by the end of this century. The growing season length on the Oak Ridges Moraine, which encompasses some of Ontario's prime agricultural land, is projected to increase by about 40 days – making it equivalent to the current growing season in some parts of Kentucky. In Algonquin Park, a centre for winter camping, average daily minimum temperatures for January are projected to increase by 5°C, making winter nights feel more like those in the city of Toronto. Tabular summaries of the remaining natural heritage areas listed in Table 3 are included in Appendix 3.

Table 4. *Current and future climate profiles for Point Pelee National Park.*

Climate Variable	1971-2000	2011-2040	2041-2070	2071-2100
Mean temperature - annual (°C)	9.4	11.2	12.9	15.0
Mean max. temperature - warmest month (°C)	27.0	29.4	30.3	33.3
Mean min. temperature - coldest month (°C)	-7.5	-5.9	-3.7	-3.5
Mean diurnal range (°C)	7.9	8.7	8.5	9.1
Annual temperature range (°C)	34.5	35.3	34.0	36.7
Growing season start - Julian date	96.0	78.0	67.0	52.0
Growing season end - Julian date	336.0	334.0	337.0	337.0
Growing season length (days)	241.0	257.0	271.0	286.1
Growing season Degree Days	2356.9	2786.2	3158.5	3816.6
Growing season mean temperature (°C)	15.1	16.3	17.1	18.8
Growing season temperature range (°C)	28.7	31.1	32.2	35.0
Precipitation - annual (mm)	866.5	857.1	849.3	815.0
Precipitation - warmest quarter (mm)	235.9	237.9	224.6	210.9
Precipitation - coldest quarter (mm)	183.6	168.0	178.0	162.0

Table 5. *Current and future climate profiles for the Oak Ridges Moraine.*

Climate Variable	1971-2000	2011-2040	2041-2070	2071-2100
Mean temperature - annual (°C)	6.6	7.9	9.5	11.4
Mean max. temperature - warmest month (°C)	25.9	27.4	28.0	30.3
Mean min. temperature - coldest month (°C)	-12.0	-9.4	-7.8	-7.7
Mean diurnal range (°C)	10.0	9.5	9.0	8.9
Annual temperature range (°C)	37.9	36.8	35.8	38.1
Growing season start - Julian date	107.0	98.5	92.3	80.9
Growing season end - Julian date	317.8	321.0	325.1	328.2
Growing season length (days)	211.8	223.5	233.8	248.3
Growing season Degree Days	1809.8	2071.3	2361.1	2853.8
Growing season mean temperature (°C)	13.9	14.7	15.6	17.0
Growing season temperature range (°C)	27.5	29.1	29.7	32.1
Precipitation - annual (mm)	859.7	863.0	870.1	869.3
Precipitation - warmest quarter (mm)	237.4	242.2	232.5	224.7



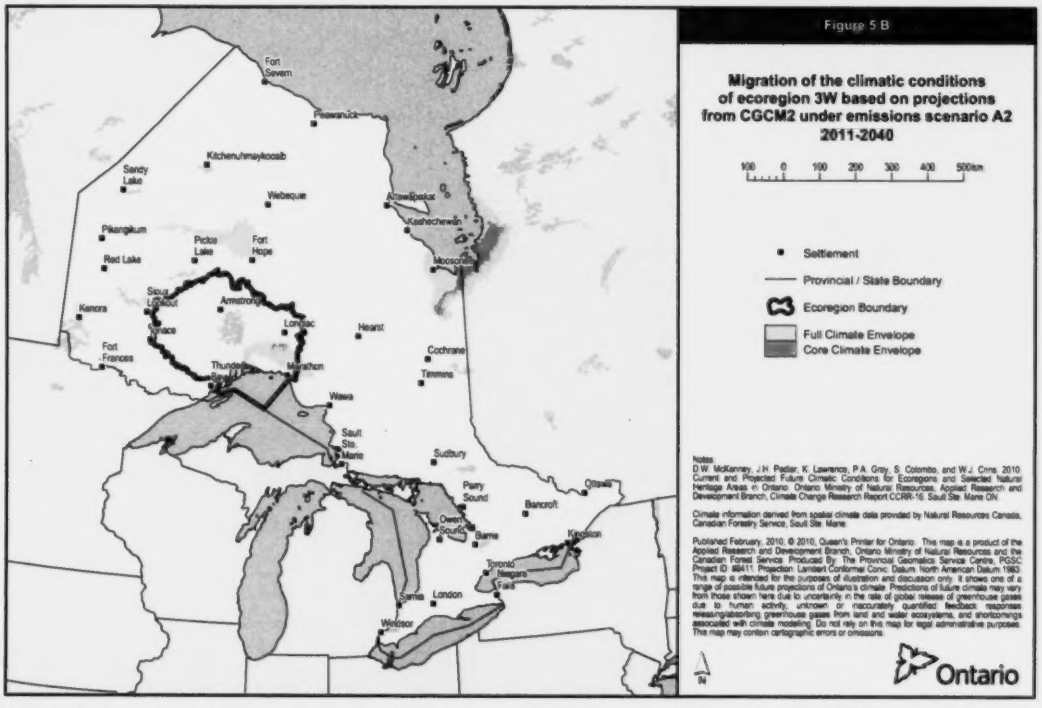


Figure 5. *Migration of the climatic conditions of ecoregion 3W based on projections from CGCM2 under emissions scenario A2 for four time periods: (a) 1971-2000, (b) 2011-2040, (c) 2041-2070, and (d) 2071-2100.*

Figure 5 C

Migration of the climatic conditions of ecoregion 3W based on projections from CGCM2 under emissions scenario A2 2041-2070

100 0 100 200 300 400 500km

- Settlement
- Provincial / State Boundary
- Ecoregion Boundary
- Full Climate Envelope
- Core Climate Envelope

Notes:
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N

Ontario

Figure 5 D

Migration of the climatic conditions of ecoregion 3W based on projections from CGCM2 under emissions scenario A2 2071-2100

100 0 100 200 300 400 500km

- Settlement
- Provincial / State Boundary
- Ecoregion Boundary
- Full Climate Envelope
- Core Climate Envelope

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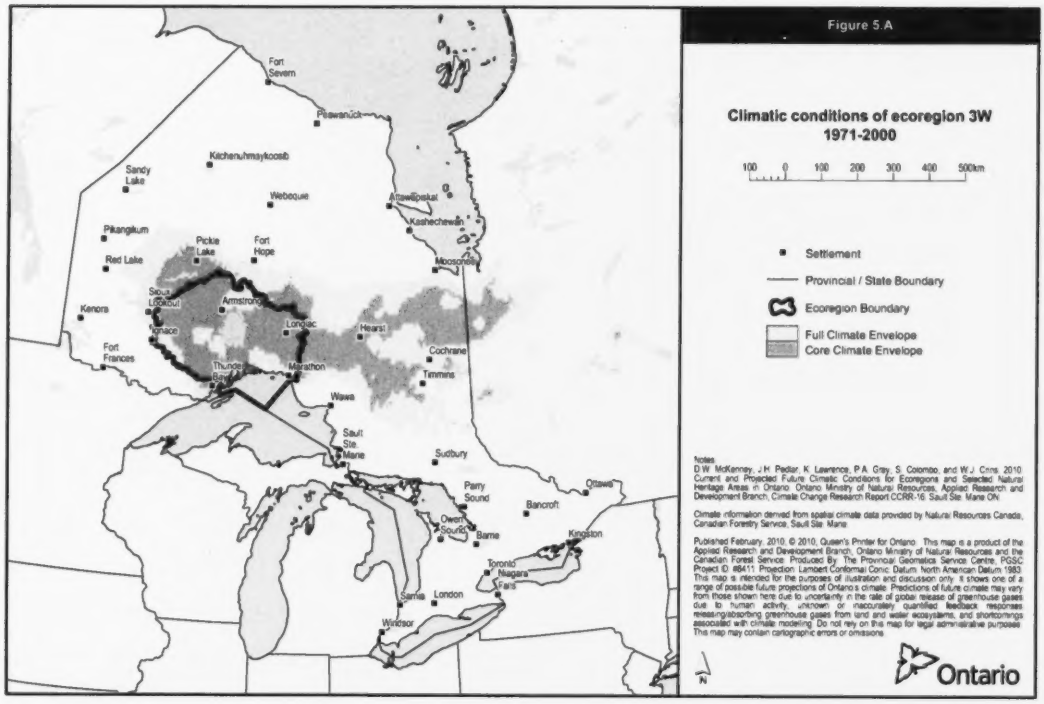
Ontario



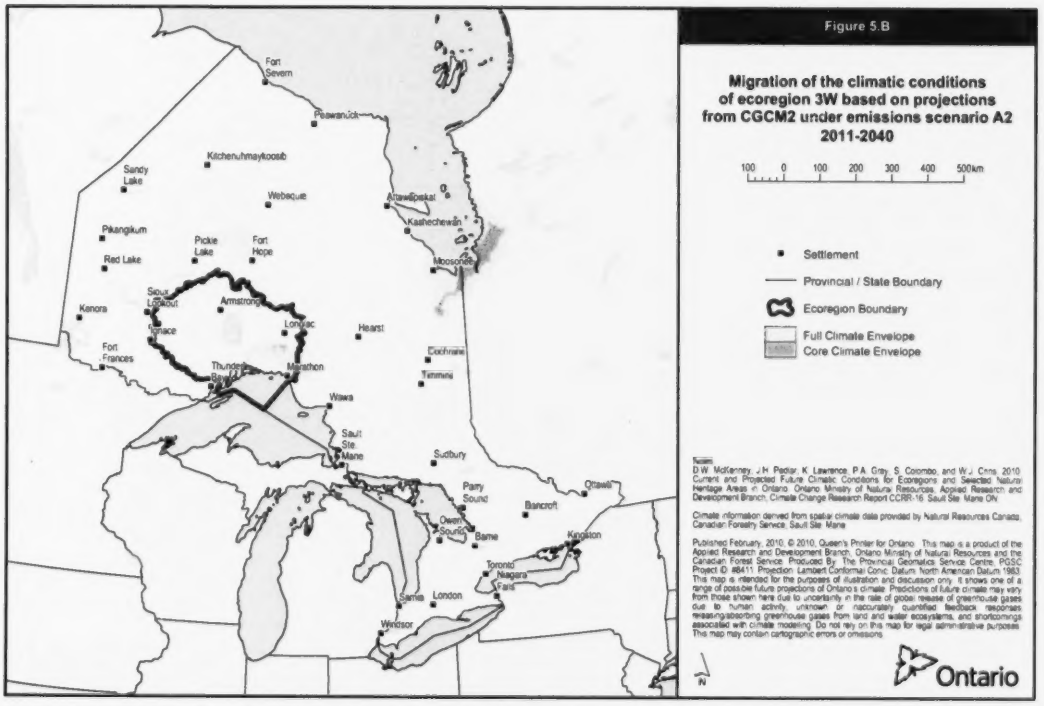


Figure 5. *Migration of the climatic conditions of ecoregion 3W based on projections from CGCM2 under emissions scenario A2 for four time periods: (a) 1971-2000, (b) 2011-2040, (c) 2041-2070, and (d) 2071-2100.*

Figure 5.C

Migration of the climatic conditions of ecoregion 3W based on projections from CGCM2 under emissions scenario A2 2041-2070

100 0 100 200 300 400 500km

- Settlement
- Provincial / State Boundary
- Ecoregion Boundary
- Full Climate Envelope
- Core Climate Envelope

Notes

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N

Ontario

Figure 5.D

Migration of the climatic conditions of ecoregion 3W based on projections from CGCM2 under emissions scenario A2 2071-2100

100 0 100 200 300 400 500km

- Settlement
- Provincial / State Boundary
- Ecoregion Boundary
- Full Climate Envelope
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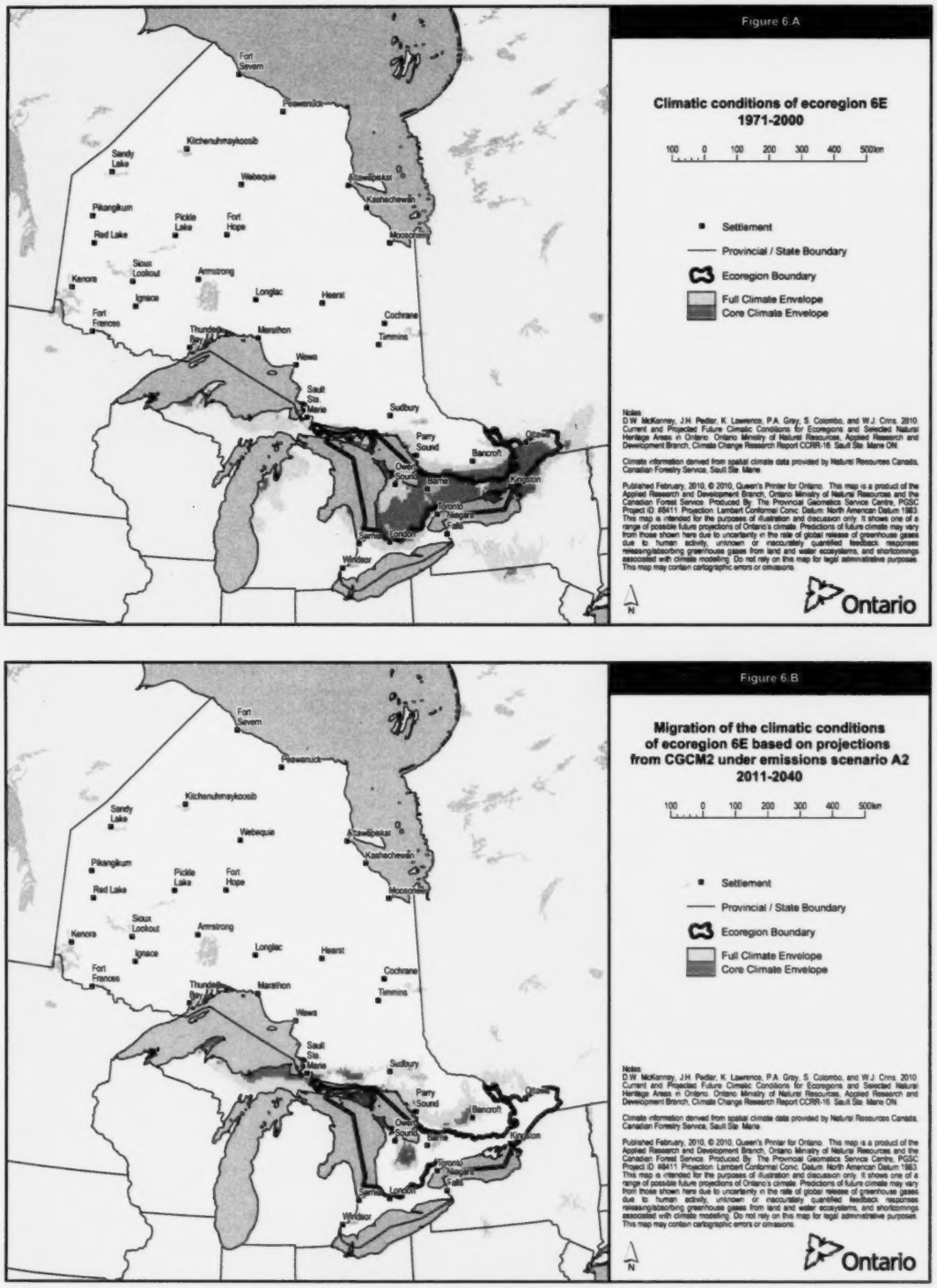
Figure 6.A
Climatic conditions of ecoregion 6E
1971-2000
100 0 100 200 300 400 500km
Settlement
Provincial / State Boundary
Ecoregion Boundary
Full Climate Envelope
Core Climate Envelope
Notes
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N
Ontario
Figure 6.B
Migration of the climatic conditions
of ecoregion 6E based on projections
from CGCM2 under emissions scenario A2
2011-2040
100 0 100 200 300 400 500km
Settlement
Provincial / State Boundary
Ecoregion Boundary
Full Climate Envelope
Core Climate Envelope
Notes
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N
Ontario

Figure 6. *Migration of the climatic conditions of ecoregion 6E based on projections from CGCM2 under emissions scenario A2 for four time periods: (a) 1971-2000, (b) 2011-2040, (c) 2041-2070, and (d) 2071-2100.*

Figure 6.C

Migration of the climatic conditions of ecoregion 6Ebased on projections from CGCM2 under emissions scenario A2 2041-2070

100 0 100 200 300 400 500km

- Settlement
- Provincial / State Boundary
- Ecoregion Boundary
- Full Climate Envelope
- Core Climate Envelope

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N

Ontario

Figure 6.D

Migration of the climatic conditions of ecoregion 6Ebased on projections from CGCM2 under emissions scenario A2 2071-2100

100 0 100 200 300 400 500km

- Settlement
- Provincial / State Boundary
- Ecoregion Boundary
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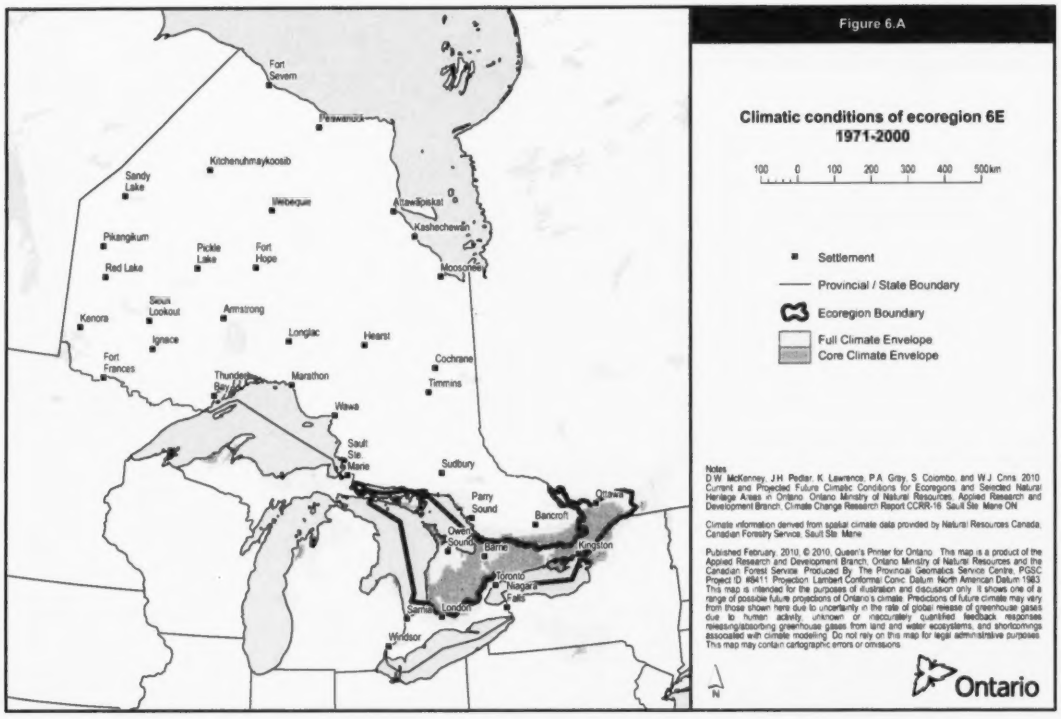
Figure 6.A
Climatic conditions of ecoregion 6E
1971-2000
100 0 100 200 300 400 500km
Settlement
Provincial / State Boundary
Ecoregion Boundary
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Ontario
Fort Severn
Peawanuck
Kitchenuhmaykoosib
Sandy Lake
Webequie
Attawapiskat
Kashechewan
Pikangikum
Pickle Lake
Fort Hope
Red Lake
Moosonee
Sioux Lookout
Armstrong
Kenora
Ignace
Longlac
Hearst
Fort Frances
Cochrane
Thunder Bay
Marathon
Timmins
Wawa
Sault Ste. Marie
Sudbury
Parry Sound
Ottawa
Bancroft
Owen Sound
Barrie
Kingston
Toronto
Niagara Falls
Sarnia
London
Windsor

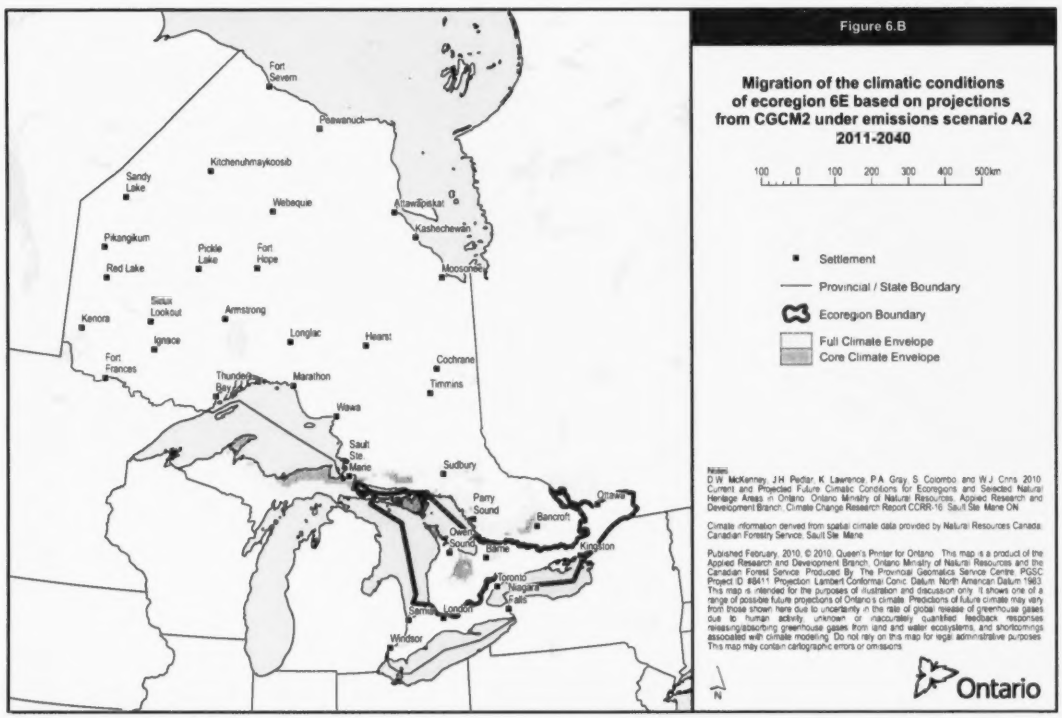
Figure 6.B
Migration of the climatic conditions
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from CGCM2 under emissions scenario A2
2011-2040
100 0 100 200 300 400 500km
Settlement
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N
Ontario
Fort Severn
Peawanuck
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Sandy Lake
Webequie
Attawapiskat
Kashechewan
Pikangikum
Pickle Lake
Fort Hope
Red Lake
Moosonee
Sioux Lookout
Armstrong
Kenora
Ignace
Longlac
Hearst
Fort Frances
Cochrane
Thunder Bay
Marathon
Timmins
Wawa
Sault Ste. Marie
Sudbury
Parry Sound
Ottawa
Bancroft
Owen Sound
Barrie
Kingston
Toronto
Niagara Falls
Sarnia
London
Windsor

Figure 6. *Migration of the climatic conditions of ecoregion 6E based on projections from CGCM2 under emissions scenario A2 for four time periods: (a) 1971-2000, (b) 2011-2040, (c) 2041-2070, and (d) 2071-2100.*

Figure 6.C

Migration of the climatic conditions of ecoregion 6Ebased on projections from CGCM2 under emissions scenario A2 2041-2070

100 0 100 200 300 400 500km

- Settlement
- Provincial / State Boundary
- Ecoregion Boundary
- Full Climate Envelope
- Core Climate Envelope

Notes:
D.W. McKenney, J.H. Pedlar, K. Lawrence, P.A. Gray, S. Colombo, and W.J. Crins. 2010. Current and Projected Future Climatic Conditions for Ecoregions and Selected Natural Heritage Areas in Ontario. Ontario Ministry of Natural Resources. Applied Research and Development Branch. Climate Change Research Report CCRR-16. Sault Ste. Marie ON.

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Ontario

Figure 6.D

Migration of the climatic conditions of ecoregion 6Ebased on projections from CGCM2 under emissions scenario A2 2071-2100

100 0 100 200 300 400 500km

- Settlement
- Provincial / State Boundary
- Ecoregion Boundary
- Full Climate Envelope
- Core Climate Envelope

Notes:
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Ontario

Table 6. Current and future climate profiles for Algonquin Provincial Park.

Climate Variable	1971-2000	2011-2040	2041-2070	2071-2100
Mean temperature - annual (°C)	3.7	4.9	6.3	8.1
Mean max. temperature - warmest month (°C)	24.5	26.2	26.8	28.8
Mean min. temperature - coldest month (°C)	-18.6	-16.1	-13.8	-13.6
Mean diurnal range (°C)	11.7	11.6	11.1	10.8
Annual temperature range (°C)	43.1	42.3	40.6	42.5
Growing season start - Julian date	117.0	114.0	109.6	100.9
Growing season end - Julian date	299.5	300.6	308.4	315.5
Growing season length (days)	183.5	187.6	199.8	215.7
Growing season Degree Days	1447.4	1655.0	1892.1	2284.0
Growing season mean temperature (°C)	13.3	14.3	14.9	16.1
Growing season temperature range (°C)	26.1	27.9	28.4	30.6
Precipitation - annual (mm)	956.4	980.1	987.9	989.4
Precipitation - warmest quarter (mm)	265.1	290.4	285.3	278.0
Precipitation - coldest quarter (mm)	207.4	196.3	201.4	205.2

Table 7. Current and future climate profiles for Polar Bear Provincial Park.

Climate Variable	1971-2000	2011-2040	2041-2070	2071-2100
Mean temperature - annual (°C)	-4.5	-3.2	-1.1	1.6
Mean max. temperature - warmest month (°C)	17.3	19.4	20.7	22.8
Mean min. temperature - coldest month (°C)	-29.1	-26.7	-21.9	-20.1
Mean diurnal range (°C)	9.5	9.5	8.9	8.1
Annual temperature range (°C)	46.4	46.2	42.6	42.8
Growing season start - Julian date	155.4	152.6	144.9	130.6
Growing season end - Julian date	288.8	291.8	297.0	299.4
Growing season length (days)	134.4	140.2	153.0	169.8
Growing season Degree Days	531.4	688.7	906.0	1270.3
Growing season mean temperature (°C)	9.2	10.2	11.3	12.9
Growing season temperature range (°C)	19.2	21.3	22.5	24.6
Precipitation - annual (mm)	518.7	541.5	556.9	579.7
Precipitation - warmest quarter (mm)	209.0	226.2	237.8	246.3
Precipitation - coldest quarter (mm)	64.1	60.7	61.3	61.1

Climatic Suitability of Natural Heritage Areas for Selected Tree Species

The projected climatic suitability of Ontario's network of natural heritage areas for select tree species varies greatly (Table 8). For boreal species (i.e., black spruce, jack pine, white spruce, balsam fir, and trembling aspen) as the century progresses the amount of area with suitable climate available in natural heritage areas is projected to decline. This is not surprising as much of the current climate for these species is projected to migrate northwards out of the province. For tree species of the Great Lakes-St. Lawrence forest region (i.e., white pine, red pine, sugar maple, and red oak), the amount of suitable habitat is projected to increase as many of the larger northern parks become warmer. As the province warms, southern deciduous species (i.e., tulip, poplar, black walnut, and shagbark hickory) are projected to have more areas with suitable climate in Ontario's protected areas. The potential gains for these species are dramatic for the full climatic range but minimal for core (optimal) climate, suggesting that much of the province may still be only marginally suitable for them. Maps of the climate envelopes for each tree species and time period are available at http://planthardiness.gc.ca/.

Table 8. *Percentage of natural heritage areas projected to be climatically suitable for selected tree species in each of four time periods. Results are shown for both full and core climatic ranges.*

Species	1971-2000		2011-2040		2041-2070		2071-2100	
	Full	Core	Full	Core	Full	Core	Full	Core
Boreal								
Black spruce	100.0	67.8	99.6	52.0	98.0	43.8	76.4	25.3
White spruce	100.0	74.5	100.0	77.5	98.8	58.6	76.7	26.9
Jack pine	100.0	64.4	99.7	54.2	99.4	53.6	98.4	26.6
Balsam fir	100.0	55.2	99.8	51.1	99.4	47.8	90.0	19.1
Trembling aspen	100.0	72.9	100.0	75.5	100.0	86.0	99.3	41.2
Great Lakes-St. Lawrence								
White pine	69.6	26.5	74.9	40.2	88.6	54.8	99.8	41.6
Red pine	57.2	27.1	73.0	35.2	79.1	50.5	99.3	14.0
Sugar maple	42.2	16.7	59.3	29.6	79.5	38.3	99.8	47.6
Red oak	37.2	7.8	51.2	20.9	72.6	24.3	96.1	37.4
Southern Deciduous								
Tulip poplar	28.7	0.0	45.0	0.0	57.2	0.0	63.7	0.0
Black walnut	26.6	0.0	40.7	0.0	53.7	0.0	75.9	0.2
Shagbark hickory	10.1	0.0	20.6	0.2	32.5	0.2	36.9	2.5

We also examined the projected movement of the climate envelope for black spruce (Table 9), sugar maple (Table 10), and shagbark hickory (Table 11) across the 29 selected natural heritage areas. Note that this work simply identifies the projected shift in the climate envelope for each tree species; whether a species actually migrates with the changing climate envelope is a much more complex issue that is discussed below. As the century progresses, for all species the general pattern is a northward movement of optimal climate into northern natural heritage areas, accompanied by a loss of optimal climate in southern natural heritage areas. By the end of this century, core climate for black spruce is projected to remain only in Polar Bear Provincial Park along the Hudson Bay coast and in Pukaskwa National Park on the northeastern shore of Lake Superior; none of the natural heritage areas in southern Ontario are projected to be suitable (Table 9). Core climatic range for sugar maple is projected to reach locations as far north as Mojikit Lake

Table 9. *Presence/absence (1/0) of suitable climate habitat (full and core range) for black spruce in each of the 29 selected natural heritage areas for each of four time periods.*

Protected Natural Area	Ecoregion	Full Range				Core Range			
		1971-2000	2011-2040	2041-2070	2071-2100	1971-2000	2011-2040	2041-2070	2071-2100
Oak Ridges Moraine	6E	1	1	1	0	0	0	0	0
Rouge Park	6E	1	1	0	0	0	0	0	0
Niagara Escarpment	6E/7E	1	1	1	0	1	0	0	0
Mojikit Lake Conservation Reserve	3W	1	1	1	1	1	1	0	0
Wabakimi Provincial Park	3W	1	1	1	1	1	1	1	0
Woodland Caribou Provincial Park	4S	1	1	1	1	1	1	0	0
Willow Lake Conservation Reserve	3S	1	1	1	1	1	0	0	0
Twilight Lake Conservation Reserve	3S	1	1	1	0	1	0	0	0
The Pinery Provincial Park	7E	1	1	0	0	0	0	0	0
St. Lawrence Islands National Park	6E	1	1	1	0	0	0	0	0
Rondeau Provincial Park	7E	1	0	0	0	0	0	0	0
Quetico Provincial Park	4W	1	1	1	1	1	0	0	0
Pukaskwa National Park	3E	1	1	1	1	1	1	1	1
Presqu'ile Provincial Park	6E	1	1	0	0	0	0	0	0
Polar Bear Provincial Park	0E/1E	1	1	1	1	1	1	1	1
Point Pelee National Park	7E	1	0	0	0	0	0	0	0
Opasquia Provincial Park	2W	1	1	1	1	1	1	1	0
N. of the N. French River Cons. Res.	3E	1	1	1	1	1	1	1	0
National Capital Commission	6E	1	1	1	0	0	0	0	0
Long Point Provincial Park	7E	1	0	0	0	0	0	0	0
Lake of the Woods Provincial Park	4S	1	1	1	0	1	0	0	0
Lady Evelyn-Smoothwater Provincial Park	4E	1	1	1	1	1	1	0	0
Killarney Provincial Park	5E	1	1	1	1	1	0	0	0
Kesagami Provincial Park	3E	1	1	1	1	1	1	1	0
Jog Lake Conservation Reserve	2E	1	1	1	1	1	1	1	0
Georgian Bay Islands National Park	5E	1	1	1	0	0	0	0	0
Charleston Lake Provincial Park	6E	1	1	1	0	0	0	0	0
Bruce Peninsula National Park	6E	1	1	1	0	0	0	0	0
Algonquin Provincial Park	5E	1	1	1	1	1	0	0	0

Conservation Reserve and Wabakimi Provincial Park in northwestern Ontario; the full climatic range is projected to reach as far north as Polar Bear Provincial Park (Table 10). Finally, by the end of the century marginal climatic habitat for shagbark hickory is projected to appear as far north as Algonquin and Quetico Provincial Parks (Table 11). Data tables for all tree species listed in Table 2 are included in Appendix 4.

Table 10. *Presence/absence (1/0) of suitable climate habitat (full and core range) for sugar maple in each of the 29 selected natural heritage areas for each of four time periods.*

Protected Natural Area	Ecoregion	Full Range				Core Range			
		1971-2000	2011-2040	2041-2070	2071-2100	1971-2000	2011-2040	2041-2070	2071-2100
Oak Ridges Moraine	6E	1	1	1	1	1	1	1	0
Rouge Park	6E	1	1	1	1	0	0	0	0
Niagara Escarpment	6E/7E	1	1	1	1	1	1	1	1
Mojikit Lake Conservation Reserve	3W	0	0	1	1	0	0	0	1
Wabakimi Provincial Park	3W	0	1	1	1	0	0	1	1
Woodland Caribou Provincial Park	4S	1	1	1	1	0	0	0	0
Willow Lake Conservation Reserve	3S	1	1	1	1	0	0	1	1
Twilight Lake Conservation Reserve	3S	1	1	1	1	0	0	0	0
The Pinery Provincial Park	7E	1	1	1	1	1	0	0	0
St. Lawrence Islands National Park	6E	1	1	1	1	0	1	1	0
Rondeau Provincial Park	7E	1	1	1	1	1	1	0	0
Quetico Provincial Park	4W	1	1	1	1	0	1	1	1
Pukaskwa National Park	3E	1	1	1	1	0	1	1	1
Presqu'ile Provincial Park	6E	1	1	0	0	0	0	0	0
Polar Bear Provincial Park	0E/1E	0	0	1	1	0	0	0	0
Point Pelee National Park	7E	1	1	1	0	1	0	0	0
Opasquia Provincial Park	2W	0	1	1	1	0	0	0	0
N. of the N. French River Cons. Res.	3E	0	1	1	1	0	0	1	1
National Capital Commission	6E	1	1	1	1	1	1	1	1
Long Point Provincial Park	7E	1	1	1	1	1	1	1	0
Lake of the Woods Provincial Park	4S	1	1	1	1	0	0	0	0
Lady Evelyn-Smoothwater Provincial Park	4E	1	1	1	1	1	1	1	1
Killarney Provincial Park	5E	1	1	1	1	0	0	0	0
Kesagami Provincial Park	3E	0	1	1	1	0	0	1	1
Jog Lake Conservation Reserve	2E	0	1	1	1	0	0	0	0
Georgian Bay Islands National Park	5E	1	1	1	1	1	1	1	1
Charleston Lake Provincial Park	6E	1	1	1	1	1	1	1	0
Bruce Peninsula National Park	6E	1	1	1	1	0	0	0	0
Algonquin Provincial Park	5E	1	1	1	1	1	1	1	1

Table 11. *Presence/absence (1/0) of suitable climate habitat (full and core range) for shagbark hickory in each of the 29 selected natural heritage areas for each of four time periods.*

Protected Natural Area	Ecoregion	Full Range				Core Range			
		1971-2000	2011-2040	2041-2070	2071-2100	1971-2000	2011-2040	2041-2070	2071-2100
Oak Ridges Moraine	6E	1	1	1	1	0	0	0	0
Rouge Park	6E	1	1	1	1	0	0	0	0
Niagara Escarpment	6E/7E	1	1	1	1	0	1	1	0
Mojikit Lake Conservation Reserve	3W	0	0	0	0	0	0	0	0
Wabakimi Provincial Park	3W	0	0	0	0	0	0	0	0
Woodland Caribou Provincial Park	4S	0	0	0	0	0	0	0	0
Willow Lake Conservation Reserve	3S	0	0	0	0	0	0	0	0
Twilight Lake Conservation Reserve	3S	0	0	0	0	0	0	0	0
The Pinery Provincial Park	7E	1	1	1	1	0	0	0	0
St. Lawrence Islands National Park	6E	1	1	1	1	0	0	0	0
Rondeau Provincial Park	7E	1	1	1	1	0	0	0	0
Quetico Provincial Park	4W	0	0	1	1	0	0	0	0
Pukaskwa National Park	3E	0	1	1	1	0	0	0	0
Presqu'ile Provincial Park	6E	1	0	0	0	0	0	0	0
Polar Bear Provincial Park	0E/1E	0	0	0	0	0	0	0	0
Point Pelee National Park	7E	1	1	1	0	0	0	0	0
Opasquia Provincial Park	2W	0	0	0	0	0	0	0	0
N. of the N. French River Cons. Res.	3E	0	0	0	0	0	0	0	0
National Capital Commission	6E	1	1	1	1	0	0	1	0
Long Point Provincial Park	7E	1	1	1	1	0	0	0	0
Lake of the Woods Provincial Park	4S	0	0	0	0	0	0	0	0
Lady Evelyn-Smoothwater Provincial Park	4E	0	0	1	1	0	0	0	0
Killarney Provincial Park	5E	1	1	1	1	0	0	0	0
Kesagami Provincial Park	3E	0	0	0	0	0	0	0	0
Jog Lake Conservation Reserve	2E	0	0	0	0	0	0	0	0
Georgian Bay Islands National Park	5E	1	1	1	1	0	0	0	0
Charleston Lake Provincial Park	6E	1	1	1	1	0	0	0	0
Bruce Peninsula National Park	6E	1	1	1	1	0	0	0	0
Algonquin Provincial Park	5E	0	1	1	1	0	0	0	1

Discussion

Our results project substantial changes in climate across Ontario's ecoregions during this century. These changes raise questions about the usefulness of the ecoregion framework for future ecosystem management and planning. Current ecoregions are defined primarily by climate, but also incorporate geological features and vegetation patterns into boundary definitions (Baldwin et al. 1998). Under climate change, temperature gradients are projected to shift rapidly, vegetation will likely migrate at a slower rate, and geological features are expected to remain in place. Where does this leave current ecoregion boundaries? One option would be to retain current ecoregion boundaries and track climate conditions in them through time. This may provide a useful means of expressing the extent of disequilibrium between

climate and existing vegetation over time. At the same time, identifying where former ecoregion climates have migrated to could provide a guide for planned adaptation that is linked to large-scale ecological function.

Given the powerful influence of latitude on temperature, the northward shift in ecoregion climate envelopes during the early part of this century is not surprising. However, the pattern observed here that climate envelopes get increasingly smaller and more scattered, or even disappear, as the century progresses does not follow from a simple northward migration of current climate conditions. We suggest this pattern results from a rapid northward shift in temperature in combination with relatively stable annual precipitation patterns (as seen in Figures 3 and 4). This asynchrony between major climatic gradients may result in novel climate combinations for large portions of the province. Williams et al. (2007) made global projections of "novel and disappearing" climates and identified the climate of northern Ontario as being at risk of disappearing by 2100.

There were large shifts in the climate envelopes of the tree species studied here, indicating potential changes in species composition across Ontario's network of natural heritage areas. There are several important points concerning these findings. First, we do not suggest that tree populations will actually follow the projected shifts in climate. We simply identify where the climatic conditions in which a tree species currently grows are projected to move to; the extent to which tree species will actually shift with climate, through natural and/or assisted migration, is highly uncertain. Second, the above analysis, in which species' climate envelopes are essentially moved across the province like chess pieces, ignores several important genetic considerations (see Aitken et al. 2008 for thorough discussion). Most importantly, populations tend to be adapted to local climate. Thus, as climate changes, trees in many locations may exhibit a decrease in growth even though they may remain well within the known climatic range of the species – if this maladaptation becomes too severe then disease, mortality, and competitive displacement are likely to follow. Conversely, the situation may arise where a species persists in a location even though the climate has changed beyond its known climatic limits. For instance, this may occur along the southern edge of a species' distribution, particularly when the range limit is determined by non-climatic factors such as competitive interactions or a physical barrier. Finally, our climate envelope approach does not take into account the potential effect of increased atmospheric carbon levels on plant responses to changing climatic conditions (i.e., the CO_2 fertilization effect). In particular, plants may show increased tolerance to moisture stress and modest temperature increases under elevated CO_2 levels (Wullschleger et al. 2002). While this may translate into slight inaccuracies in the tree climate envelopes presented here during the early stages of climate change, the effects of CO_2 fertilization are not likely to persist at the temperature increases projected for the mid-to-late part of this century. Despite these points, we suggest that this analysis has value in that it provides a sense of the magnitude of the problem that climate change poses for plant species and helps to inform the scale at which assisted migration efforts would have to be undertaken to successfully promote plant conservation.

Given the projected shift in the distribution and abundance of plants, animals, and other organisms, some natural heritage areas may, at some point, cease to preserve the suite of flora and fauna for which they were originally established. If no action is taken, widespread species may continue to be well represented within the system, but rare and endangered species that are restricted to only a few locations, may become extirpated. One option to offset the effects of climate change includes the use of assisted migration techniques to establish native species threatened by climate change. Natural heritage areas could be used as both sources of and centres to reestablish these species. At this point in the development of adaptation strategies and techniques, it is important to recognize that implementation of assisted migration strategies will require a philosophical shift for many natural heritage area managers who have traditionally worked to

maintain and/or preserve natural ecosystem processes with minimal human interference. Nonetheless, if climate change progresses as projected, assisted migration may be a necessary approach for conserving some species – and protected natural heritage areas represent a ready-made network of potential transplant locations. A healthy debate on the role and proper application of assisted colonization has begun in the scientific literature (McLachlan et al. 2007, Hunter 2007, Hoegh-Guldberg 2008, Ricciardi and Simberloff 2008). Citizen groups (e.g., the Torreya Guardians) have already started to transplant species of interest (McLachlan et al. 2007).

Any discussion of future climate projections is not complete without recognizing the uncertainties involved. We provided results for two emissions scenarios to cover a range of potential outcomes, but uncertainty remains about how much and how quickly greenhouse gas emissions will grow during the 21st century. While this introduces uncertainty, the IPCC (2007) suggests that even if emissions were to remain at year 2000 levels, temperature would still increase by about 1°C during this century. Over the past two decades, the GCMs have been continuously improved and the IPCC (2007) deems their projections to be *very likely*; nonetheless, unforeseen factors and interactions that alter the rate of climate change in unexpected ways are possible. Another major source of uncertainty is how flora and fauna will respond to changes in climate. Among the many unanswered questions: Will plants survive in situ better than anticipated due to physiological plasticity and the CO_2 fertilization effect? What role will altered disturbance regimes (e.g., fire) and invasive species play in shaping plant and animal distributions? Will human-assisted migration play a role in plant conservation efforts? Clearly there are many unknowns in projecting ecosystem responses to climate change. The results presented here are intended as a starting point for discussions around climate change adaptation and mitigation.

Recommendations

As existing climate envelopes migrate and new climate envelopes emerge, ecosystem composition, structure, and function will change. In many cases, species distribution and abundance also will change. These changes will require adaptive responses by resource managers, which could be enhanced by:

1. **Education:** Encourage resource managers to use the time series maps to highlight the extent and speed of potential changes in climate.

2. **More green space:** To assist natural species migration, increase forest cover, connectivity, and patch size where these ecological elements are lacking.

3. **Effective monitoring programs:** Develop integrated monitoring programs to help detect and verify change as it occurs. This will help to guide strategic decisionmaking and calibrate future modelling efforts.

4. **Ongoing ecoregion assessments**: Regularly review the usefulness of Ontario's ecosystem framework to ensure relevance and appropriate use in the context of a rapidly changing climate.

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Appendix 1.

Projected change in six climate variables for each of Ontario's ecoregions based on average outputs from four GCMs under emissions scenario A2 for four time periods. See text for climate variable definitions.

Eco-region	Climate Variable	1971-200			2011-2040			2041-2070			2071-2100		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
OE	AMT	-5.3	-3.9	-4.8	-4.0	-2.5	-3.5	-2.3	-0.8	-1.8	0.5	2.2	1.1
	MAXT	17.5	18.6	18.0	19.6	21.0	20.3	20.9	22.4	21.7	23.0	24.9	24.0
	MINT	-30.9	-29.8	-30.4	-28.9	-27.7	-28.6	-25.7	-23.3	-24.9	-21.7	-18.5	-20.2
	ANNP	458.0	542.0	505.0	457.0	567.8	511.5	468.5	580.3	522.0	502.3	618.0	555.3
	PRECWQ	192.0	230.0	213.0	205.0	245.3	228.0	204.8	246.8	227.8	213.5	246.3	231.8
	PRECCQ	55.0	63.0	59.0	42.0	67.0	50.5	46.8	75.0	56.3	53.8	90.0	65.8
1E	AMT	-5.0	-2.4	-3.8	-3.7	-1.0	-2.5	-2.1	0.7	-0.9	0.6	3.5	1.9
	MAXT	17.7	21.4	19.4	20.1	23.0	21.5	21.4	24.5	22.9	23.5	27.2	25.4
	MINT	-30.8	-29.5	-30.1	-28.9	-27.4	-28.3	-25.9	-23.2	-24.8	-22.5	-18.7	-20.5
	ANNP	486.0	581.0	537.0	479.8	604.0	547.8	490.0	613.8	557.3	522.0	643.8	586.8
	PRECWQ	205.0	248.0	227.0	216.5	261.5	243.0	216.8	261.5	242.8	223.0	258.5	243.5
	PRECCQ	58.0	71.0	65.0	41.3	78.3	56.8	44.8	86.3	62.5	52.0	99.8	72.5
2E	AMT	-3.1	0.5	-1.1	-1.8	1.8	0.3	-0.1	3.3	1.8	2.7	5.7	4.4
	MAXT	20.2	24.9	23.0	22.3	26.1	24.4	23.7	27.5	25.9	26.4	29.9	28.4
	MINT	-29.7	-26.3	-28.5	-28.0	-24.8	-26.7	-24.6	-21.5	-23.4	-21.2	-18.2	-20.1
	ANNP	508.0	762.0	628.0	581.8	751.3	639.8	585.0	765.3	650.0	603.0	790.3	671.3
	PRECWQ	214.0	256.0	237.0	195.5	271.5	243.8	193.5	270.8	243.3	185.3	269.3	234.8
	PRECCQ	66.0	143.0	94.0	59.3	131.8	86.8	64.3	145.8	96.0	71.3	162.3	108.0
2W	AMT	-3.4	0.3	-1.7	-2.1	1.6	-0.4	-0.5	3.2	1.1	2.2	5.5	3.6
	MAXT	19.8	24.6	22.5	22.0	25.8	24.1	23.5	27.4	25.7	26.1	29.9	28.3
	MINT	-29.9	-27.0	-28.9	-28.5	-25.1	-27.5	-25.5	-22.3	-24.5	-22.7	-18.9	-21.4
	ANNP	527.0	736.0	630.0	516.8	769.3	640.5	524.8	780.8	648.0	548.3	798.3	665.0
	PRECWQ	225.0	275.0	256.0	229.0	300.8	267.0	231.5	303.3	269.5	220.8	284.3	256.8
	PRECCQ	65.0	130.0	81.0	47.8	126.0	72.3	51.5	141.5	79.0	58.5	157.3	88.8
3E	AMT	-0.8	3.5	0.9	0.6	4.9	2.2	2.1	6.4	3.7	4.5	8.6	6.0
	MAXT	19.8	25.0	23.8	22.9	26.9	25.6	24.3	28.1	27.0	26.8	30.5	29.3
	MINT	-27.6	-16.4	-25.2	-26.0	-16.0	-23.6	-22.8	-13.1	-20.6	-20.1	-10.9	-17.8
	ANNP	667.0	1013.0	814.0	644.5	1046.8	842.5	651.3	1078.8	861.0	671.3	1100.0	882.0
	PRECWQ	232.0	290.0	256.0	214.0	311.0	265.8	213.5	312.0	266.8	202.8	300.5	254.0
	PRECCQ	94.0	217.0	157.0	78.3	224.5	154.3	85.3	249.8	171.3	94.5	269.8	188.0
3S	AMT	-1.1	1.3	0.0	0.0	2.4	1.1	1.6	3.9	2.6	3.9	6.2	4.9
	MAXT	22.9	24.5	23.6	24.8	26.6	25.7	26.3	28.2	27.2	28.7	30.8	29.7
	MINT	-28.6	-24.9	-27.1	-27.3	-23.8	-25.8	-24.5	-21.2	-23.1	-21.8	-18.6	-20.4
	ANNP	558.0	710.0	658.0	607.8	798.5	703.5	613.0	807.5	708.8	620.5	825.5	720.3
	PRECWQ	235.0	287.0	266.0	253.5	306.3	282.8	250.8	307.8	282.3	227.3	286.0	259.8
	PRECCQ	68.0	103.0	87.0	66.8	119.5	93.0	70.5	132.3	101.5	80.3	147.8	113.5
3W	AMT	-0.9	3.4	0.7	0.2	4.7	1.9	1.8	6.2	3.4	4.1	8.3	5.6
	MAXT	20.1	24.8	23.5	22.0	27.2	25.7	23.5	28.8	27.2	26.0	31.3	29.7
	MINT	-29.2	-17.0	-25.8	-27.7	-16.5	-24.6	-24.6	-13.5	-21.6	-22.0	-11.3	-18.9
	ANNP	663.0	868.0	739.0	709.3	886.0	788.0	713.8	908.3	800.5	720.8	927.3	815.0
	PRECWQ	234.0	283.0	257.0	245.0	302.5	272.5	241.3	298.8	268.3	222.3	279.5	249.3
	PRECCQ	81.0	170.0	121.0	87.5	191.0	125.0	99.5	212.0	140.8	108.8	231.5	154.5

Eco-region	Climate Variable	1971-200			2011-2040			2041-2070			2071-2100		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
4E	AMT	1.4	4.1	2.8	2.7	5.4	4.1	4.2	6.9	5.6	6.4	9.1	7.8
	MAXT	18.9	25.7	23.7	24.4	27.9	26.3	25.7	29.0	27.5	27.9	31.3	29.8
	MINT	-23.6	-16.1	-20.6	-22.3	-15.1	-19.3	-19.5	-12.4	-16.6	-17.2	-10.2	-14.3
	ANNP	765.0	1113.0	883.0	833.8	1184.3	947.5	854.5	1226.0	975.5	868.0	1251.0	993.5
	PRECWQ	220.0	299.0	249.0	234.8	305.0	262.5	233.0	304.8	262.5	214.8	294.3	249.0
	PRECCQ	139.0	271.0	192.0	148.5	289.8	194.3	162.8	320.0	213.3	177.3	345.3	232.8
4S	AMT	0.5	2.9	1.8	1.7	4.1	3.0	3.2	5.5	4.5	5.5	7.8	6.7
	MAXT	23.9	25.7	24.8	26.0	28.2	27.2	27.5	29.9	28.8	30.1	32.7	31.4
	MINT	-26.6	-23.1	-24.6	-25.2	-21.8	-23.4	-22.7	-19.2	-20.8	-20.0	-16.7	-18.1
	ANNP	583.0	712.0	661.0	584.8	744.0	674.0	587.3	750.5	677.0	585.8	766.8	682.8
	PRECWQ	253.0	299.0	281.0	241.8	292.0	271.5	236.0	287.3	266.5	210.0	265.3	241.5
	PRECCQ	64.0	94.0	76.0	70.8	107.0	84.5	77.3	118.5	92.8	86.3	132.0	103.3
4W	AMT	1.4	3.3	2.3	2.3	4.7	3.5	3.8	6.1	5.0	6.0	8.4	7.2
	MAXT	23.1	25.8	24.9	25.9	28.4	27.4	27.4	30.0	29.0	29.8	32.7	31.6
	MINT	-24.8	-19.7	-23.3	-24.6	-18.4	-22.2	-21.7	-15.5	-19.3	-19.0	-13.2	-16.9
	ANNP	691.0	839.0	733.0	713.0	868.3	775.0	720.3	887.5	785.3	718.8	900.3	792.5
	PRECWQ	250.0	297.0	282.0	259.0	298.0	285.3	249.8	286.5	274.5	230.3	267.0	253.5
	PRECCQ	67.0	143.0	99.0	74.5	149.5	108.0	83.3	168.5	121.3	91.5	184.3	133.5
5E	AMT	2.2	6.3	4.5	3.6	7.6	5.8	5.1	9.2	7.3	7.2	11.4	9.5
	MAXT	21.8	27.0	25.4	25.3	29.0	27.6	26.5	30.2	28.6	28.5	32.9	31.0
	MINT	-20.6	-14.1	-17.9	-19.3	-13.0	-16.6	-16.9	-10.9	-14.4	-14.8	-8.4	-12.1
	ANNP	793.0	1141.0	949.0	797.3	1227.5	952.3	834.5	1272.5	989.5	827.5	1299.0	999.5
	PRECWQ	215.0	299.0	250.0	212.8	310.5	256.0	214.5	311.0	257.5	198.0	300.8	244.5
	PRECCQ	152.0	297.0	216.0	151.0	313.3	210.3	164.5	345.5	228.5	178.8	372.5	248.0
5S	AMT	2.8	3.2	3.0	3.9	4.3	4.1	5.3	5.7	5.6	7.6	8.1	7.8
	MAXT	25.4	25.9	25.7	28.1	28.4	28.2	29.8	30.1	30.0	32.5	32.9	32.7
	MINT	-24.1	-23.0	-23.5	-23.0	-21.7	-22.3	-20.2	-19.3	-19.7	-17.7	-16.8	-17.2
	ANNP	617.0	693.0	659.0	616.5	700.0	663.3	620.5	706.0	668.5	618.0	705.5	666.5
	PRECWQ	273.0	291.0	283.0	260.8	287.3	276.5	253.3	278.8	268.5	227.5	252.8	242.0
	PRECCQ	61.0	82.0	73.0	68.5	82.3	75.8	75.0	89.8	82.5	83.0	99.5	91.5
6E	AMT	4.7	8.1	6.4	6.0	9.5	7.7	7.6	11.0	9.2	9.7	13.3	11.4
	MAXT	23.0	27.4	25.6	25.5	29.3	27.9	26.6	30.4	29.0	28.9	33.1	31.4
	MINT	-18.6	-9.7	-12.9	-17.0	-9.0	-12.2	-14.7	-7.0	-10.1	-12.6	-4.6	-7.7
	ANNP	741.0	1111.0	926.0	783.8	1074.8	911.8	803.5	1118.3	951.5	809.5	1126.5	953.5
	PRECWQ	205.0	290.0	237.0	200.8	285.0	239.8	205.3	297.8	240.8	185.8	284.5	226.8
	PRECCQ	137.0	307.0	221.0	138.0	297.8	214.8	149.3	319.5	230.3	162.0	343.8	247.3
7E	AMT	7.3	10.0	8.6	8.5	11.1	9.9	10.0	12.6	11.5	12.2	14.8	13.7
	MAXT	25.8	28.8	27.1	28.8	30.6	29.4	29.9	32.0	30.7	32.5	34.8	33.3
	MINT	-11.2	-8.0	-9.1	-10.5	-7.1	-8.7	-8.5	-5.1	-6.5	-6.1	-2.8	-4.2
	ANNP	776.0	1012.0	911.0	777.5	1022.0	908.0	810.3	1066.5	940.0	809.0	1052.3	933.8
	PRECWQ	216.0	275.0	249.0	221.3	279.0	251.8	221.3	278.8	248.8	204.8	262.0	235.5
	PRECCQ	154.0	229.0	192.0	160.5	228.3	192.5	168.5	241.3	202.3	173.3	252.0	211.3

Appendix 2.

Projected change in six climate variables for each of Ontario's ecoregions based on average outputs from four GCMs under emissions scenario B2 for four time periods. See text for climate variable definitions.

Eco-region	Climate Variable	1971-200			2011-2040			2041-2070			2071-2100		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
OE	AMT	-5.3	-3.9	-4.8	-3.8	-2.4	-3.3	-2.8	-1.2	-2.3	-1.5	0.3	-0.9
	MAXT	17.5	18.6	18.0	19.7	21.1	20.4	20.8	22.1	21.5	21.6	23.1	22.4
	MINT	-30.9	-29.8	-30.4	-28.7	-27.0	-28.1	-26.8	-24.4	-26.0	-24.5	-21.0	-23.3
	ANNP	458.0	542.0	505.0	455.5	558.0	505.8	478.5	584.5	530.8	490.8	598.5	542.0
	PRECWQ	192.0	230.0	213.0	205.5	244.5	227.3	214.0	254.8	236.5	214.0	248.8	232.8
	PRECCQ	55.0	63.0	59.0	43.5	70.5	52.3	45.3	73.3	54.3	50.0	81.5	60.3
1E	AMT	-5.0	-2.4	-3.8	-3.6	-0.8	-2.4	-2.6	0.3	-1.3	-1.3	1.7	0.0
	MAXT	17.7	21.4	19.4	20.1	23.2	21.6	21.2	24.2	22.6	22.1	25.3	23.6
	MINT	-30.8	-29.5	-30.1	-28.8	-26.6	-27.9	-27.1	-24.4	-26.0	-24.9	-21.2	-23.3
	ANNP	486.0	581.0	537.0	476.8	595.3	541.0	501.0	619.8	566.3	511.0	629.0	575.3
	PRECWQ	205.0	248.0	227.0	217.3	261.3	242.3	226.8	272.3	252.5	224.3	264.3	246.3
	PRECCQ	58.0	71.0	65.0	43.0	80.8	58.8	44.0	83.3	60.8	47.5	94.8	66.8
2E	AMT	-3.1	0.5	-1.1	-1.6	2.0	0.5	-0.6	3.0	1.4	0.8	4.2	2.7
	MAXT	20.2	24.9	23.0	22.4	26.1	24.5	23.5	27.3	25.6	24.6	28.4	26.8
	MINT	-29.7	-26.3	-28.5	-27.6	-24.0	-25.9	-25.9	-23.0	-24.8	-23.5	-19.9	-22.0
	ANNP	508.0	762.0	628.0	573.5	748.0	634.3	587.3	764.5	651.8	592.8	776.3	660.5
	PRECWQ	214.0	256.0	237.0	195.5	271.0	243.5	197.5	279.8	251.0	189.3	271.0	240.5
	PRECCQ	66.0	143.0	94.0	60.8	137.3	90.8	63.3	139.8	92.3	67.5	152.5	101.3
2W	AMT	-3.4	0.3	-1.7	-2.0	1.9	-0.2	-0.9	2.7	0.7	0.4	3.9	1.9
	MAXT	19.8	24.6	22.5	22.1	26.0	24.3	23.2	27.1	25.3	24.3	28.2	26.6
	MINT	-29.9	-27.0	-28.9	-28.0	-24.5	-26.9	-27.0	-23.8	-26.0	-25.0	-21.0	-23.8
	ANNP	527.0	736.0	630.0	512.3	764.0	633.8	537.3	778.8	653.8	540.8	789.3	658.3
	PRECWQ	225.0	275.0	256.0	230.5	300.3	268.0	241.0	308.3	275.5	231.0	298.5	268.3
	PRECCQ	65.0	130.0	81.0	49.5	134.3	75.8	50.3	135.0	75.8	54.3	146.8	82.5
3E	AMT	-0.8	3.5	0.9	0.8	5.2	2.5	1.7	6.0	3.4	3.0	7.2	4.6
	MAXT	19.8	25.0	23.8	23.1	26.8	25.7	24.2	27.9	26.8	25.3	29.0	27.9
	MINT	-27.6	-16.4	-25.2	-25.3	-15.0	-22.9	-24.4	-14.5	-22.2	-21.8	-12.1	-19.5
	ANNP	667.0	1013.0	814.0	637.0	1047.8	841.5	652.8	1061.3	856.0	659.3	1079.8	869.3
	PRECWQ	232.0	290.0	256.0	215.5	313.3	267.8	218.0	318.3	271.0	209.0	307.8	260.8
	PRECCQ	94.0	217.0	157.0	80.3	229.8	159.3	83.0	240.0	164.3	89.5	251.8	176.0
3S	AMT	-1.1	1.3	0.0	0.3	2.8	1.4	1.1	3.5	2.2	2.4	4.7	3.4
	MAXT	22.9	24.5	23.6	25.0	26.9	25.9	26.0	28.0	26.9	27.0	29.0	28.0
	MINT	-28.6	-24.9	-27.1	-26.6	-23.1	-25.1	-25.9	-22.7	-24.6	-24.1	-20.8	-22.7
	ANNP	558.0	710.0	658.0	602.0	793.8	698.0	615.8	806.8	707.5	612.3	816.3	711.8
	PRECWQ	235.0	287.0	266.0	250.8	306.3	282.3	245.5	309.8	280.3	243.5	303.5	277.3
	PRECCQ	68.0	103.0	87.0	68.5	127.8	97.8	68.8	126.5	97.8	73.8	137.8	105.5
3W	AMT	-0.9	3.4	0.7	0.5	5.0	2.2	1.3	5.8	3.0	2.6	7.0	4.2
	MAXT	20.1	24.8	23.5	22.3	27.4	25.8	23.5	28.5	27.0	24.5	29.6	28.0
	MINT	-29.2	-17.0	-25.8	-26.9	-15.5	-23.7	-26.2	-15.1	-23.2	-24.2	-12.7	-21.1
	ANNP	663.0	868.0	739.0	707.5	886.5	787.5	703.3	891.8	789.3	713.3	909.5	803.0
	PRECWQ	234.0	283.0	257.0	243.5	298.8	270.8	236.5	298.3	268.0	229.0	292.5	261.8
	PRECCQ	81.0	170.0	121.0	94.0	197.0	132.3	93.3	204.5	133.5	102.5	215.0	143.5

Eco-region	Climate Variable	1971-200			2011-2040			2041-2070			2071-2100		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
4E	AMT	1.4	4.1	2.8	3.0	5.7	4.4	3.8	6.5	5.3	5.0	7.8	6.5
	MAXT	18.9	25.7	23.7	24.5	27.8	26.3	25.6	28.9	27.4	26.6	30.0	28.5
	MINT	-23.6	-16.1	-20.6	-21.6	-14.1	-18.5	-20.8	-13.7	-18.0	-18.4	-11.3	-15.5
	ANNP	765.0	1113.0	883.0	834.0	1186.3	949.0	853.0	1205.3	967.8	862.3	1225.8	979.8
	PRECWQ	220.0	299.0	249.0	235.5	304.8	263.0	238.5	304.3	265.3	223.0	297.8	255.5
	PRECCQ	139.0	271.0	192.0	151.8	294.8	198.3	159.0	309.0	207.8	167.3	321.5	217.3
4S	AMT	0.5	2.9	1.8	2.0	4.4	3.4	2.8	5.2	4.1	4.0	6.4	5.3
	MAXT	23.9	25.7	24.8	26.3	28.4	27.5	27.3	29.7	28.5	28.4	30.8	29.6
	MINT	-26.6	-23.1	-24.6	-24.6	-21.0	-22.7	-24.1	-20.6	-22.3	-22.3	-18.3	-20.3
	ANNP	583.0	712.0	661.0	585.0	742.8	672.8	575.5	741.5	667.0	576.5	750.8	671.5
	PRECWQ	253.0	299.0	281.0	238.8	287.5	268.5	227.3	280.3	259.5	226.5	279.3	258.3
	PRECCQ	64.0	94.0	76.0	74.0	113.8	88.8	75.8	114.0	90.0	78.0	122.0	95.0
4W	AMT	1.4	3.3	2.3	2.7	5.0	3.8	3.4	5.8	4.6	4.6	7.0	5.8
	MAXT	23.1	25.8	24.9	26.0	28.6	27.6	27.1	29.8	28.8	28.2	30.9	29.8
	MINT	-24.8	-19.7	-23.3	-23.7	-17.4	-21.4	-23.3	-17.1	-20.9	-21.2	-14.7	-18.7
	ANNP	691.0	839.0	733.0	710.3	866.8	772.0	701.8	865.5	767.5	708.3	879.8	777.5
	PRECWQ	250.0	297.0	282.0	254.5	291.3	278.5	249.0	285.8	271.3	240.0	279.8	265.5
	PRECCQ	67.0	143.0	99.0	78.0	156.5	113.3	80.0	160.5	115.5	84.3	171.5	122.5
5E	AMT	2.2	6.3	4.5	3.9	7.9	6.1	4.7	8.8	6.9	5.9	10.0	8.2
	MAXT	21.8	27.0	25.4	25.3	29.0	27.4	26.3	30.2	28.5	27.5	31.3	29.6
	MINT	-20.6	-14.1	-17.9	-18.5	-12.2	-15.9	-18.1	-11.8	-15.5	-15.8	-9.4	-13.1
	ANNP	793.0	1141.0	949.0	807.5	1229.5	961.0	831.0	1251.0	985.3	822.3	1272.3	988.0
	PRECWQ	215.0	299.0	250.0	216.8	313.8	259.0	221.3	314.3	261.3	210.5	307.3	254.0
	PRECCQ	152.0	297.0	216.0	153.5	318.0	213.8	160.8	334.0	225.0	167.0	347.0	231.0
5S	AMT	2.8	3.2	3.0	4.2	4.6	4.4	5.1	5.5	5.3	6.2	6.6	6.4
	MAXT	25.4	25.9	25.7	28.4	28.7	28.6	29.6	29.9	29.7	30.7	31.1	30.9
	MINT	-24.1	-23.0	-23.5	-22.3	-21.1	-21.6	-21.7	-20.7	-21.1	-19.6	-18.2	-18.8
	ANNP	617.0	693.0	659.0	617.3	699.3	663.8	605.0	688.0	651.3	607.5	692.5	655.3
	PRECWQ	273.0	291.0	283.0	256.5	281.0	270.8	244.0	270.0	259.0	242.8	267.3	257.5
	PRECCQ	61.0	82.0	73.0	71.5	85.5	79.0	73.0	87.0	80.5	75.0	90.5	83.0
6E	AMT	4.7	8.1	6.4	6.4	9.8	8.0	7.2	10.7	8.9	8.4	11.9	10.1
	MAXT	23.0	27.4	25.6	25.5	29.1	27.8	26.6	30.3	28.9	27.7	31.4	30.0
	MINT	-18.6	-9.7	-12.9	-16.5	-8.4	-11.5	-15.8	-7.8	-11.0	-13.6	-5.6	-8.7
	ANNP	741.0	1111.0	926.0	786.5	1090.8	924.0	803.3	1115.0	946.5	800.8	1109.3	941.3
	PRECWQ	205.0	290.0	237.0	206.5	291.5	244.0	208.5	294.5	245.8	198.0	292.5	237.5
	PRECCQ	137.0	307.0	221.0	140.3	304.3	217.8	146.3	315.8	228.0	151.5	320.0	230.5
7E	AMT	7.3	10.0	8.6	8.8	11.4	10.2	9.7	12.3	11.1	10.9	13.5	12.4
	MAXT	25.8	28.8	27.1	28.6	30.4	29.2	29.7	31.6	30.4	30.9	32.9	31.6
	MINT	-11.2	-8.0	-9.1	-9.8	-6.5	-7.9	-9.4	-6.1	-7.4	-7.3	-4.0	-5.5
	ANNP	776.0	1012.0	911.0	789.5	1041.3	923.0	807.8	1057.5	938.5	799.3	1042.3	925.5
	PRECWQ	216.0	275.0	249.0	227.0	287.3	259.5	226.5	285.3	257.3	217.5	274.8	247.5
	PRECCQ	154.0	229.0	192.0	163.8	232.3	195.3	166.3	238.0	200.0	165.5	237.0	199.0

Appendix 3.

Current and projected future climate for 29 natural heritage areas in Ontario for four time periods based on CGCM2 and the A2 emissions scenario.

Natural Heritage Area	Climate Variable	Time Period			
		1971-2000	2011-2040	2041-2070	2071-2100
Algonquin Provincial Park	Mean temperature - annual (°C)	3.7	4.9	6.3	8.1
	Mean max. temperature - warmest month (°C)	24.5	26.2	26.8	28.8
	Mean min. temperature - coldest month (°C)	-18.6	-16.1	-13.8	-13.6
	Mean diurnal range (°C)	11.7	11.6	11.1	10.8
	Annual temperature range (°C)	43.1	42.3	40.6	42.5
	Growing season start - Julian date	117.0	114.0	109.6	100.9
	Growing season end - Julian date	299.5	300.6	308.4	315.5
	Growing season length (days)	183.5	187.6	199.8	215.7
	Growing season Degree Days	1447.4	1655	1892.1	2284
	Growing season mean temperature (°C)	13.3	14.3	14.9	16.1
	Growing season temperature range (°C)	26.1	27.9	28.4	30.6
	Precipitation - annual (mm)	956.4	980.1	987.9	989.4
	Precipitation - warmest quarter (mm)	265.1	290.4	285.3	278.0
	Precipitation - coldest quarter (mm)	207.4	196.3	201.4	205.2
Bruce Peninsula National Park	Mean temperature - annual (°C)	5.9	7.2	8.7	10.5
	Mean max. temperature - warmest month (°C)	23.2	24.8	25.4	27.5
	Mean min. temperature - coldest month (°C)	-11.3	-9.7	-6.9	-6.7
	Mean diurnal range (°C)	8.4	8.4	7.9	7.7
	Annual temperature range (°C)	34.5	34.4	32.2	34.2
	Growing season start - Julian date	112.7	107.6	101.0	89.8
	Growing season end - Julian date	323.2	325.6	328.3	331.1
	Growing season length (days)	211.5	219.1	228.3	242.3
	Growing season Degree Days	1559.3	1815.1	2085	2530.5
	Growing season mean temperature (°C)	12.7	13.7	14.6	15.9
	Growing season temperature range (°C)	24.9	26.6	27.0	29.4
	Precipitation - annual (mm)	911.0	875.1	879.4	880.2
	Precipitation - warmest quarter (mm)	208.7	212.7	205.2	202.4
	Precipitation - coldest quarter (mm)	253.2	229.3	238.6	237.9
Charleston Lake Provincial Park	Mean temperature - annual (°C)	6.7	8.0	9.5	11.3
	Mean max. temperature - warmest month (°C)	26.1	28.1	28.8	31
	Mean min. temperature - coldest month (°C)	-13.6	-11.1	-9.0	-9.0
	Mean diurnal range (°C)	10.0	10.1	9.7	9.5
	Annual temperature range (°C)	39.7	39.2	37.8	40.0
	Growing season start - Julian date	105.2	98.7	93.2	84.8
	Growing season end - Julian date	319.6	321.2	324.8	327.7
	Growing season length (days)	215.4	223.5	232.6	243.9
	Growing season Degree Days	1918.4	2196.7	2487.8	2958.7
	Growing season mean temperature (°C)	14.3	15.3	16.2	17.6
	Growing season temperature range (°C)	27.8	30.0	30.6	32.9
	Precipitation - annual (mm)	937.2	928.2	948.4	945.0
	Precipitation - warmest quarter (mm)	232.6	234.7	231.0	219.8
	Precipitation - coldest quarter (mm)	217.8	210.0	221.0	225.3

Natural Heritage Area	Climate Variable	Time Period			
		1971-2000	2011-2040	2041-2070	2071-2100
Georgian Bay Islands National Park	Mean temperature - annual (°C)	6.2	7.6	9.1	11.0
	Mean max. temperature - warmest month (°C)	25.3	27.1	27.7	29.9
	Mean min. temperature - coldest month (°C)	-13.4	-10.3	-8.3	-8.1
	Mean diurnal range (°C)	9.8	9.7	9.2	8.9
	Annual temperature range (°C)	38.7	37.4	36.0	38.0
	Growing season start - Julian date	109.1	101.8	95.5	86.7
	Growing season end - Julian date	319.7	322.2	325.4	328.2
	Growing season length (days)	211.6	221.4	230.8	242.5
	Growing season Degree Days	1789.4	2043	2319.9	2777.2
	Growing season mean temperature (°C)	13.8	14.7	15.5	16.9
	Growing season temperature range (°C)	26.9	28.9	29.4	31.7
	Precipitation - annual (mm)	1032.5	1027.3	1037.3	1038.8
	Precipitation - warmest quarter (mm)	245.4	244.7	236.5	231.8
	Precipitation - coldest quarter (mm)	282.5	288.4	300.7	301.5
Jog Lake Conservation Area	Mean temperature - annual (°C)	0.0	1.3	2.6	4.6
	Mean max. temperature - warmest month (°C)	24.0	24.8	25.7	27.7
	Mean min. temperature - coldest month (°C)	-26.6	-24.2	-20.9	-18.6
	Mean diurnal range (°C)	12.7	12.2	11.9	11.5
	Annual temperature range (°C)	50.6	49.0	46.6	46.3
	Growing season start - Julian date	131.0	130.7	125.1	117.1
	Growing season end - Julian date	290.1	294	298.8	300.8
	Growing season length (days)	160.1	164.3	174.7	184.7
	Growing season Degree Days	1140.7	1324.8	1549.2	1935
	Growing season mean temperature (°C)	12.6	13.6	14.4	15.9
	Growing season temperature range (°C)	25.7	26.5	27.3	29.5
	Precipitation - annual (mm)	699.9	690.4	696.8	715.4
	Precipitation - warmest quarter (mm)	239.5	234.9	244.1	225.2
	Precipitation - coldest quarter (mm)	119.4	106.0	110.1	113.6
Kesagami Provincial Park	Mean temperature - annual (°C)	-0.8	0.5	1.9	3.7
	Mean max. temperature - warmest month (°C)	22.5	23.9	24.6	26.4
	Mean min. temperature - coldest month (°C)	-26.5	-24.8	-21.2	-19.1
	Mean diurnal range (°C)	12.0	11.5	11.2	10.8
	Annual temperature range (°C)	48.9	48.7	45.9	45.5
	Growing season start - Julian date	133.8	131.3	127.0	119.9
	Growing season end - Julian date	290.2	293.2	298.6	301.1
	Growing season length (days)	157.4	163.0	172.6	182.1
	Growing season Degree Days	998.1	1184.4	1384.9	1712.8
	Growing season mean temperature (°C)	11.7	12.7	13.5	14.9
	Growing season temperature range (°C)	24.1	25.7	26.3	28.2
	Precipitation - annual (mm)	732.2	767.7	778.1	768.9
	Precipitation - warmest quarter (mm)	258.5	267.8	275.2	249.1
	Precipitation - coldest quarter (mm)	117.7	105.0	106.6	109.6

Natural Heritage Area	Climate Variable	Time Period			
		1971-2000	2011-2040	2041-2070	2071-2100
Killarney Provincial Park	Mean temperature - annual (°C)	4.5	5.8	7.2	9.0
	Mean max. temperature - warmest month (°C)	24.8	26.6	27.2	29.2
	Mean min. temperature - coldest month (°C)	-17.0	-14.1	-11.5	-11.2
	Mean diurnal range (°C)	10.7	10.4	9.9	9.6
	Annual temperature range (°C)	41.8	40.7	38.7	40.4
	Growing season start - Julian date	114.8	111.1	107.7	98.8
	Growing season end - Julian date	307.2	311.9	316	320.2
	Growing season length (days)	193.5	201.8	209.3	222.4
	Growing season Degree Days	1548.6	1798.6	2037.2	2438.2
	Growing season mean temperature (°C)	13.4	14.3	15.2	16.4
	Growing season temperature range (°C)	26.5	28.4	28.9	31.1
	Precipitation - annual (mm)	900.5	901.4	905.5	914.1
	Precipitation - warmest quarter (mm)	223.4	223.4	219.1	213.6
	Precipitation - coldest quarter (mm)	204.9	195.7	202.7	205.8
Lake of the Woods Provincial Park	Mean temperature - annual (°C)	2.6	4.1	5.4	7.7
	Mean max. temperature - warmest month (°C)	25.1	27.3	28.2	30.7
	Mean min. temperature - coldest month (°C)	-23.3	-20.4	-17.5	-14.9
	Mean diurnal range (°C)	11.7	11.5	11.6	11.4
	Annual temperature range (°C)	48.4	47.6	45.7	45.6
	Growing season start - Julian date	117.2	110.0	105.2	93.8
	Growing season end - Julian date	295.6	298.0	300.6	302.9
	Growing season length (days)	179.4	189.0	196.4	210.1
	Growing season Degree Days	1540.8	1842.2	2056.7	2544.3
	Growing season mean temperature (°C)	14.1	15.2	16.0	17.6
	Growing season temperature range (°C)	26.8	29.2	30.0	32.6
	Precipitation - annual (mm)	625.7	614	606.8	604.8
	Precipitation - warmest quarter (mm)	275.1	266.3	259.8	223
	Precipitation - coldest quarter (mm)	69.1	69.7	66.7	70.3
Lady Evelyn Smoothwater Provincial Park	Mean temperature - annual (°C)	2.3	3.4	4.7	6.4
	Mean max. temperature - warmest month (°C)	24.1	25.4	26.0	27.9
	Mean min. temperature - coldest month (°C)	-21.8	-19.7	-15.7	-14.9
	Mean diurnal range (°C)	11.4	11.0	10.6	10.1
	Annual temperature range (°C)	46.0	45.1	41.6	42.8
	Growing season start - Julian date	121.0	119.5	117.1	112.6
	Growing season end - Julian date	296.6	299.4	304.1	309.1
	Growing season length (days)	176.7	180.9	187.9	197.6
	Growing season Degree Days	1352.4	1550.2	1767.9	2120.9
	Growing season mean temperature (°C)	13.1	14.0	14.9	16.2
	Growing season temperature range (°C)	25.8	27.2	27.6	29.6
	Precipitation - annual (mm)	835.1	865.2	869.7	873.0
	Precipitation - warmest quarter (mm)	248.0	270.0	270.2	257.0
	Precipitation - coldest quarter (mm)	165.8	159.1	163.0	167.7

Natural Heritage Area	Climate Variable	Time Period			
		1971-2000	2011-2040	2041-2070	2071-2100
Long Point Provincial Park	Mean temperature - annual (°C)	8.7	10.2	11.9	13.9
	Mean max. temperature - warmest month (°C)	26.1	28.5	29.3	32.0
	Mean min. temperature - coldest month (°C)	-8.2	-6.2	-4.2	-4.1
	Mean diurnal range (°C)	8.7	9.2	8.9	9.1
	Annual temperature range (°C)	34.3	34.7	33.5	36.2
	Growing season start - Julian date	100.0	84.0	75.0	57.0
	Growing season end - Julian date	333.0	332.0	335.0	336.0
	Growing season length (days)	234.0	249.0	261.0	280.0
	Growing season Degree Days	2143.0	2502.0	2855.0	3454.0
	Growing season mean temperature (°C)	14.5	15.5	16.4	17.8
	Growing season temperature range (°C)	27.6	30.3	30.9	33.8
	Precipitation - annual (mm)	971.0	973.0	974.0	953.0
	Precipitation - warmest quarter (mm)	250.0	255.0	242.0	228.0
	Precipitation - coldest quarter (mm)	209.0	203.0	216.0	204.0
Mojikit Lake Conservation Reserve	Mean temperature - annual (°C)	-0.7	0.5	1.8	3.9
	Mean max. temperature - warmest month (°C)	23.3	25.0	25.8	28.0
	Mean min. temperature - coldest month (°C)	-28.1	-25.6	-22.7	-20.5
	Mean diurnal range (°C)	12.9	12.6	12.4	12.0
	Annual temperature range (°C)	51.3	50.6	48.6	48.6
	Growing season start - Julian date	134.2	132.5	127.1	120.0
	Growing season end - Julian date	287.6	291.0	296	298.0
	Growing season length (days)	154.4	159.5	169.9	179.0
	Growing season Degree Days	1068	1245.5	1463.2	1859.9
	Growing season mean temperature (°C)	12.3	13.3	14.1	15.9
	Growing season temperature range (°C)	25.0	26.8	27.6	29.8
	Precipitation - annual (mm)	728.6	724.3	724.3	742.4
	Precipitation - warmest quarter (mm)	263.6	272.2	277.9	250.3
	Precipitation - coldest quarter (mm)	108.6	92.7	95.1	98.1
National Capital Commission Land	Mean temperature - annual (°C)	5.7	6.9	8.4	10.1
	Mean max. temperature - warmest month (°C)	26.5	27.9	28.6	30.6
	Mean min. temperature - coldest month (°C)	-15.9	-13.3	-11.1	-11.0
	Mean diurnal range (°C)	10.5	10.2	9.7	9.5
	Annual temperature range (°C)	42.3	41.1	39.7	41.7
	Growing season start - Julian date	107.6	104.0	99.3	91.0
	Growing season end - Julian date	312.2	316.5	320.1	323.8
	Growing season length (days)	205.6	213.5	221.8	233.8
	Growing season Degree Days	1829.3	2107.1	2371.4	2803.5
	Growing season mean temperature (°C)	14.3	15.3	16.1	17.5
	Growing season temperature range (°C)	28.1	29.6	30.2	32.5
	Precipitation - annual (mm)	916.7	907.7	925.5	922.5
	Precipitation - warmest quarter (mm)	257.7	256.3	254.8	244.9
	Precipitation - coldest quarter (mm)	200.6	193.5	200.9	207.4

Natural Heritage Area	Climate Variable	Time Period			
		1971-2000	2011-2040	2041-2070	2071-2100
Niagara Escarpment	Mean temperature - annual (°C)	6.5	8.0	9.5	11.4
	Mean max. temperature - warmest month (°C)	25.0	26.8	27.4	29.8
	Mean min. temperature - coldest month (°C)	-11.1	-8.8	-6.9	-6.8
	Mean diurnal range (°C)	9.3	9.0	8.6	8.5
	Annual temperature range (°C)	36.1	35.6	34.3	36.5
	Growing season start - Julian date	108.9	99.5	92.9	80.1
	Growing season end - Julian date	320.2	323.8	327.5	330.1
	Growing season length (days)	212.3	225.3	235.6	251.0
	Growing season Degree Days	1754.9	2045.9	2335.0	2824.9
	Growing season mean temperature (°C)	13.6	14.5	15.3	16.7
	Growing season temperature range (°C)	26.6	28.6	29.1	31.6
	Precipitation - annual (mm)	961.3	935.6	940.2	936.6
	Precipitation - warmest quarter (mm)	242.0	246.3	235.9	230.0
	Precipitation - coldest quarter (mm)	240.3	223.4	234.2	230.0
North French River Conservation Reserve	Mean temperature - annual (°C)	-0.5	0.8	2.1	3.9
	Mean max. temperature - warmest month (°C)	22.8	24.2	24.9	26.7
	Mean min. temperature - coldest month (°C)	-26.4	-24.5	-21.0	-18.8
	Mean diurnal range (°C)	12.1	11.6	11.3	10.8
	Annual temperature range (°C)	49.1	48.7	45.9	45.5
	Growing season start - Julian date	133.0	130.0	126.0	119.3
	Growing season end - Julian date	290.9	293.8	299.0	301.2
	Growing season length (days)	158.9	164.7	174.0	182.9
	Growing season Degree Days	1029.4	1231.8	1437.6	1761.7
	Growing season mean temperature (°C)	11.9	12.9	13.7	15.1
	Growing season temperature range (°C)	24.4	26.0	26.6	28.4
	Precipitation - annual (mm)	768.2	781.7	791.1	783.5
	Precipitation - warmest quarter (mm)	262.6	267.1	274.3	248.0
	Precipitation - coldest quarter (mm)	132.7	112.6	114.2	117.8
Oak Ridges Moraine	Mean temperature - annual (°C)	6.6	7.9	9.5	11.4
	Mean max. temperature - warmest month (°C)	25.9	27.4	28	30.3
	Mean min. temperature - coldest month (°C)	-12.0	-9.4	-7.8	-7.7
	Mean diurnal range (°C)	10.0	9.5	9.0	8.9
	Annual temperature range (°C)	37.9	36.8	35.8	38.1
	Growing season start - Julian date	107.0	98.5	92.3	80.9
	Growing season end - Julian date	317.8	321.0	325.1	328.2
	Growing season length (days)	211.8	223.5	233.8	248.3
	Growing season Degree Days	1809.8	2071.3	2361.1	2853.8
	Growing season mean temperature (°C)	13.9	14.7	15.6	17.0
	Growing season temperature range (°C)	27.5	29.1	29.7	32.1
	Precipitation - annual (mm)	859.7	863.0	870.1	869.3
	Precipitation - warmest quarter (mm)	237.4	242.2	232.5	224.7
	Precipitation - coldest quarter (mm)	182.9	179.8	188.9	186.7

Natural Heritage Area	Climate Variable	Time Period			
		1971-2000	2011-2040	2041-2070	2071-2100
Opasquia Provincial Park	Mean temperature - annual (°C)	-1.4	-0.1	1.3	3.7
	Mean max. temperature - warmest month (°C)	22.2	23.8	24.8	27.3
	Mean min. temperature - coldest month (°C)	-27.6	-25.1	-22.8	-20.8
	Mean diurnal range (°C)	10.2	10.2	10.1	10.0
	Annual temperature range (°C)	49.8	48.9	47.7	48.1
	Growing season start - Julian date	131.4	130.9	124.6	116.1
	Growing season end - Julian date	291.5	292.3	295.5	297.0
	Growing season length (days)	161.1	162.4	171.9	181.9
	Growing season Degree Days	1078.0	1262.4	1489.0	1893.4
	Growing season mean temperature (°C)	12.0	13.2	14.1	15.9
	Growing season temperature range (°C)	23.9	25.6	26.5	29.0
	Precipitation - annual (mm)	582.9	559.1	555.9	547.7
	Precipitation - warmest quarter (mm)	247.5	251.5	252.0	231.4
	Precipitation - coldest quarter (mm)	71.2	53.0	48.6	51.7
Pinery Provincial Park	Mean temperature - annual (°C)	8.0	9.7	11.3	13.3
	Mean max. temperature - warmest month (°C)	26.4	28.5	29.2	31.8
	Mean min. temperature - coldest month (°C)	-9.1	-6.4	-5.0	-4.8
	Mean diurnal range (°C)	9.5	9.1	8.7	8.9
	Annual temperature range (°C)	35.5	35.0	34.2	36.6
	Growing season start - Julian date	101.8	87.0	79.4	60.8
	Growing season end - Julian date	327.0	329.9	333.0	335.0
	Growing season length (days)	226.2	243.9	254.6	275.2
	Growing season Degree Days	2025.9	2400.3	2724.3	3298.8
	Growing season mean temperature (°C)	14.3	15.3	16.2	17.5
	Growing season temperature range (°C)	27.9	30.4	30.9	33.7
	Precipitation - annual (mm)	936.6	894.2	890.4	872.5
	Precipitation - warmest quarter (mm)	238.1	224.9	212.4	208.0
	Precipitation - coldest quarter (mm)	208.5	189.3	199.0	186.7
Point Pelee National Park	Mean temperature - annual (°C)	9.4	11.2	12.9	15.0
	Mean max. temperature - warmest month (°C)	27.0	29.4	30.3	33.3
	Mean min. temperature - coldest month (°C)	-7.5	-5.9	-3.7	-3.5
	Mean diurnal range (°C)	7.9	8.7	8.5	9.1
	Annual temperature range (°C)	34.5	35.3	34.0	36.7
	Growing season start - Julian date	96.0	78.0	67.0	52.0
	Growing season end - Julian date	336.0	334.0	337.0	337.0
	Growing season length (days)	241.0	257.0	271.0	286.1
	Growing season Degree Days	2356.9	2786.2	3158.5	3816.6
	Growing season mean temperature (°C)	15.1	16.3	17.1	18.8
	Growing season temperature range (°C)	28.7	31.1	32.2	35.0
	Precipitation - annual (mm)	866.5	857.1	849.3	815.0
	Precipitation - warmest quarter (mm)	235.9	237.9	224.6	210.9
	Precipitation - coldest quarter (mm)	183.6	168.0	178.0	162.0

Natural Heritage Area	Climate Variable	Time Period			
		1971-2000	2011-2040	2041-2070	2071-2100
Polar Bear Provincial Park	Mean temperature - annual (°C)	-4.5	-3.2	-1.1	1.6
	Mean max. temperature - warmest month (°C)	17.3	19.4	20.7	22.8
	Mean min. temperature - coldest month (°C)	-29.1	-26.7	-21.9	-20.1
	Mean diurnal range (°C)	9.5	9.5	8.9	8.1
	Annual temperature range (°C)	46.4	46.2	42.6	42.8
	Growing season start - Julian date	155.4	152.6	144.9	130.6
	Growing season end - Julian date	288.8	291.8	297.0	299.4
	Growing season length (days)	134.4	140.2	153.0	169.8
	Growing season Degree Days	531.4	688.7	906.0	1270.3
	Growing season mean temperature (°C)	9.2	10.2	11.3	12.9
	Growing season temperature range (°C)	19.2	21.3	22.5	24.6
	Precipitation - annual (mm)	518.7	541.5	556.9	579.7
	Precipitation - warmest quarter (mm)	209.0	226.2	237.8	246.3
	Precipitation - coldest quarter (mm)	64.1	60.7	61.3	61.1
Presqu'ile Provincial Park	Mean temperature - annual (°C)	7.4	8.9	10.5	12.3
	Mean max. temperature - warmest month (°C)	25.9	27.5	28.2	30.5
	Mean min. temperature - coldest month (°C)	-11.0	-8.1	-6.8	-6.8
	Mean diurnal range (°C)	9.4	9.1	8.6	8.5
	Annual temperature range (°C)	36.8	35.7	35.0	37.3
	Growing season start - Julian date	104.0	94.0	88.9	74.9
	Growing season end - Julian date	323.9	326.0	329.3	332.0
	Growing season length (days)	220.9	233.0	241.5	258.1
	Growing season Degree Days	1950.6	2246.8	2561.9	3063.5
	Growing season mean temperature (°C)	14.2	15.1	16.1	17.4
	Growing season temperature range (°C)	27.5	29.3	29.9	32.5
	Precipitation - annual (mm)	901.1	850.0	863.5	866.2
	Precipitation - warmest quarter (mm)	206.2	202.2	194.4	187.2
	Precipitation - coldest quarter (mm)	218.5	202.3	212.9	212.9
Pukaskwa National Park	Mean temperature - annual (°C)	1.3	2.9	4.1	5.9
	Mean max. temperature - warmest month (°C)	19.7	22.7	23.3	25.3
	Mean min. temperature - coldest month (°C)	-21.0	-18.1	-14.6	-12.4
	Mean diurnal range (°C)	10.6	10.7	10.4	9.8
	Annual temperature range (°C)	40.7	40.7	38.0	37.7
	Growing season start - Julian date	127.3	122.4	118.9	114.0
	Growing season end - Julian date	296.7	297.7	302.6	305.9
	Growing season length (days)	170.4	176.3	184.7	193.0
	Growing season Degree Days	948.3	1267.6	1478.7	1840.0
	Growing season mean temperature (°C)	11.0	12.6	13.5	15.0
	Growing season temperature range (°C)	21.5	24.3	25.0	27.0
	Precipitation - annual (mm)	882.9	927.0	936.8	964.7
	Precipitation - warmest quarter (mm)	261.9	275.8	273.5	255.9
	Precipitation - coldest quarter (mm)	183.3	188.7	203.4	209.9

Natural Heritage Area	Climate Variable	Time Period			
		1971-2000	2011-2040	2041-2070	2071-2100
Quetico Provincial Park	Mean temperature - annual (°C)	2.6	4.0	5.1	7.1
	Mean max. temperature - warmest month (°C)	24.8	26.9	27.6	29.8
	Mean min. temperature - coldest month (°C)	-22.5	-19.6	-16.2	-14.2
	Mean diurnal range (°C)	12.1	12.0	11.8	11.5
	Annual temperature range (°C)	47.4	46.5	43.9	44.0
	Growing season start - Julian date	120.1	118.7	116.0	108.1
	Growing season end - Julian date	294	297.8	301.4	303.9
	Growing season length (days)	174.9	180.1	186.4	196.7
	Growing season Degree Days	1447.7	1689.9	1885.9	2305.0
	Growing season mean temperature (°C)	13.7	14.9	15.6	17.2
	Growing season temperature range (°C)	26.5	28.7	29.4	31.7
	Precipitation - annual (mm)	710.9	743.5	741.1	761.4
	Precipitation - warmest quarter (mm)	290.1	300.3	286.8	258.0
	Precipitation - coldest quarter (mm)	81.9	86.0	90.1	92.7
Rondeau Provincial Park	Mean temperature - annual (°C)	8.9	10.7	12.4	14.5
	Mean max. temperature - warmest month (°C)	26.6	29.0	29.8	32.7
	Mean min. temperature - coldest month (°C)	-8.1	-6.0	-4.1	-3.9
	Mean diurnal range (°C)	8.6	8.9	8.7	9.1
	Annual temperature range (°C)	34.7	34.9	33.8	36.5
	Growing season start - Julian date	99.0	80.9	70.4	54.2
	Growing season end - Julian date	332.6	333.0	336.0	337.0
	Growing season length (days)	234.6	253.1	266.6	283.8
	Growing season Degree Days	2201.9	2642.1	3009.2	3637.5
	Growing season mean temperature (°C)	14.8	15.9	16.7	18.3
	Growing season temperature range (°C)	28.2	30.7	31.6	34.7
	Precipitation - annual (mm)	864.0	883.9	878.7	848.9
	Precipitation - warmest quarter (mm)	247.9	245.3	232.0	219.5
	Precipitation - coldest quarter (mm)	171.4	180.5	190.7	175.6
Rouge Park	Mean temperature - annual (°C)	7.6	8.9	10.5	12.4
	Mean max. temperature - warmest month (°C)	26.2	28.0	28.6	31.0
	Mean min. temperature - coldest month (°C)	-10.3	-8.0	-6.2	-6.1
	Mean diurnal range (°C)	9.2	9.1	8.6	8.6
	Annual temperature range (°C)	36.5	35.9	34.7	37.1
	Growing season start - Julian date	103.6	93.7	88.1	71.9
	Growing season end - Julian date	324.4	326.2	329.7	332.1
	Growing season length (days)	221.7	233.4	242.6	261.2
	Growing season Degree Days	1974.6	2247.9	2555.1	3071.6
	Growing season mean temperature (°C)	14.3	15.1	16.0	17.2
	Growing season temperature range (°C)	27.8	29.8	30.3	32.8
	Precipitation - annual (mm)	828.7	807.6	813.9	812.5
	Precipitation - warmest quarter (mm)	229.7	231.5	221.7	213.7
	Precipitation - coldest quarter (mm)	173.1	165.6	174.7	171.8

Natural Heritage Area	Climate Variable	Time Period			
		1971-2000	2011-2040	2041-2070	2071-2100
St Lawrence Islands National Park	Mean temperature - annual (°C)	7.1	8.5	10.0	11.9
	Mean max. temperature - warmest month (°C)	26.1	28.0	28.7	31.0
	Mean min. temperature - coldest month (°C)	-12.8	-10.1	-8.0	-8.0
	Mean diurnal range (°C)	9.9	9.8	9.4	9.2
	Annual temperature range (°C)	38.8	38.1	36.7	38.9
	Growing season start - Julian date	104.8	96.7	91.3	81.5
	Growing season end - Julian date	321.5	324.2	327.2	329.8
	Growing season length (days)	217.7	228.5	236.9	249.2
	Growing season Degree Days	1949.8	2268.2	2564.5	3052.3
	Growing season mean temperature (°C)	14.4	15.4	16.3	17.7
	Growing season temperature range (°C)	27.7	29.9	30.5	32.8
	Precipitation - annual (mm)	933.3	938.6	959.5	956.1
	Precipitation - warmest quarter (mm)	225.8	232.5	227.9	216.4
	Precipitation - coldest quarter (mm)	219.4	217.6	229.7	233.1
Twilight Lake Conservation Reserve	Mean temperature - annual (°C)	1.6	3.1	4.2	6.4
	Mean max. temperature - warmest month (°C)	24.1	26.2	27.2	29.6
	Mean min. temperature - coldest month (°C)	-23.6	-21.0	-18.5	-16.2
	Mean diurnal range (°C)	10.8	10.4	10.5	10.4
	Annual temperature range (°C)	47.7	47.2	45.7	45.9
	Growing season start - Julian date	120.0	117.0	112.0	102.0
	Growing season end - Julian date	295.0	297.0	300.0	302.0
	Growing season length (days)	176.0	181.0	189.0	201.0
	Growing season Degree Days	1391.8	1657.4	1852.0	2291.6
	Growing season mean temperature (°C)	13.4	14.6	15.3	16.9
	Growing season temperature range (°C)	25.8	28.1	29.0	31.6
	Precipitation - annual (mm)	683.6	675.4	663.4	662.6
	Precipitation - warmest quarter (mm)	294.0	278.0	274.0	231.0
	Precipitation - coldest quarter (mm)	76.8	82.0	78.0	83.0
Wabakimi Provincial Park	Mean temperature - annual (°C)	-0.4	0.8	2.0	4.1
	Mean max. temperature - warmest month (°C)	23.3	25.2	26.1	28.3
	Mean min. temperature - coldest month (°C)	-27.3	-25.0	-22.3	-20.1
	Mean diurnal range (°C)	12.4	12.3	12.1	11.8
	Annual temperature range (°C)	50.6	50.2	48.4	48.4
	Growing season start - Julian date	131.7	130.3	125.8	119.0
	Growing season end - Julian date	288.4	290.9	296.0	298.1
	Growing season length (days)	157.7	161.6	171.2	180.1
	Growing season Degree Days	1120.5	1297.2	1509.4	1915.5
	Growing season mean temperature (°C)	12.5	13.5	14.3	16.1
	Growing season temperature range (°C)	25.0	27.0	27.8	30.2
	Precipitation - annual (mm)	716.0	736.6	732.0	747.6
	Precipitation - warmest quarter (mm)	263.9	280.8	282.4	251.2
	Precipitation - coldest quarter (mm)	104.1	100.7	102.0	105.7

Natural Heritage Area	Climate Variable	Time Period			
		1971-2000	2011-2040	2041-2070	2071-2100
Willow Lake Conservation Reserve	Mean temperature - annual (°C)	1.2	2.2	3.4	5.4
	Mean max. temperature - warmest month (°C)	23.8	25.7	26.6	28.8
	Mean min. temperature - coldest month (°C)	-24.5	-22.6	-19.7	-17.5
	Mean diurnal range (°C)	11.3	11.2	11.0	10.7
	Annual temperature range (°C)	48.3	48.3	46.3	46.3
	Growing season start - Julian date	124.0	123.0	120.0	114.0
	Growing season end - Julian date	293.0	295.0	299.0	301.0
	Growing season length (days)	170.0	173.0	180.0	188.0
	Growing season Degree Days	1311.0	1496.0	1697.0	2101.0
	Growing season mean temperature (°C)	13.1	14.1	14.9	16.6
	Growing season temperature range (°C)	25.4	27.7	28.4	30.7
	Precipitation - annual (mm)	698.0	736.0	728.0	741.0
	Precipitation - warmest quarter (mm)	261.0	280.0	272.0	237.0
	Precipitation - coldest quarter (mm)	102.0	114.0	117.0	122.0
Woodland Caribou Provincial Park	Mean temperature - annual (°C)	1.0	2.5	3.8	6.1
	Mean max. temperature - warmest month (°C)	24.0	25.9	26.9	29.6
	Mean min. temperature - coldest month (°C)	-25.0	-22.3	-20.1	-17.8
	Mean diurnal range (°C)	11.1	10.8	11.0	10.9
	Annual temperature range (°C)	49.0	48.2	47.1	47.4
	Growing season start - Julian date	122.5	116.2	111.1	100.2
	Growing season end - Julian date	294.1	295.8	298.5	300.4
	Growing season length (days)	172.6	180.6	188.3	201.2
	Growing season Degree Days	1335.5	1606.5	1824.8	2278.1
	Growing season mean temperature (°C)	13.2	14.3	15.2	16.8
	Growing season temperature range (°C)	25.6	27.8	28.7	31.5
	Precipitation - annual (mm)	603.2	608.1	596.1	583.5
	Precipitation - warmest quarter (mm)	260.1	251.2	247.8	207.4
	Precipitation - coldest quarter (mm)	68.0	75.8	68.9	75.4

Appendix 4.

Current and future presence/absence (1/0) of suitable climate for 12 tree species in 29 natural heritage areas in Ontario for four time periods. Future climate projections are based on the CGCM2 under the A2 emissions scenario; results for both the full and core climatic ranges for each species are shown (i.e., full range/core range).

Species	Time Period	Oak Ridges Moraine	Rouge Park	Niagara Escarpment	Mojikit Lake C. R.	Wabakimi P. P.	Woodland Caribou P.P.	Willow Lake C. R.	Twilight Lake C. R.	The Pinery P. P.	St. Lawrence I. N. P.	Rondeau P. P.	Quetico P. P.	Pukaskwa N. P.	Presqu'ile P. P.	Polar Bear P. P.	Point Pelee N. P.	Opasquia P. P.	N. of N. French R. C. R.	Natl. Capital Comm.	Long Point P. P.	Lake of the Woods P. P.	Lady Ev-Smoothwater P.P.	Killarney P. P.	Kesagami P. P.	Jog Lake C. R.	Georgian Bay I. N. P.	Charleston Lake P. P.	Bruce Peninsula N. P.	Algonquin P. P.
Black spruce	1971-2000	1/0	1/0	1/1	1/1	1/1	1/1	1/1	1/1	1/0	1/0	1/0	1/1	1/1	1/0	1/1	1/0	1/1	1/1	1/0	1/0	1/1	1/1	1/1	1/1	1/1	1/0	1/0	1/0	1/1
	2011-2040	1/0	1/0	1/0	1/1	1/1	1/1	1/0	1/0	1/0	1/0	0/0	1/0	1/1	1/0	1/1	0/0	1/1	1/1	1/0	0/0	1/0	1/1	1/0	1/1	1/1	1/0	1/0	1/0	1/0
	2041-2070	1/0	0/0	1/0	1/0	1/1	1/0	1/0	1/0	0/0	1/0	0/0	1/0	1/1	0/0	1/1	0/0	1/1	1/1	1/0	0/0	1/0	1/0	1/0	1/1	1/1	1/0	1/0	1/0	1/0
	2071-2100	0/0	0/0	0/0	1/0	1/0	1/0	1/0	0/0	0/0	0/0	0/0	1/0	1/1	0/0	1/1	0/0	1/0	1/0	0/0	0/0	0/0	1/0	1/0	1/0	1/0	0/0	0/0	0/0	1/0
White spruce	1971-2000	1/0	1/0	1/1	1/1	1/1	1/1	1/1	1/1	1/0	1/0	1/0	1/1	1/1	1/0	1/1	1/0	1/1	1/1	1/0	1/0	1/1	1/1	1/1	1/1	1/1	1/1	1/0	1/1	1/1
	2011-2040	1/0	1/0	1/0	1/1	1/1	1/1	1/1	1/0	1/0	1/0	0/0	1/0	1/1	1/0	1/1	0/0	1/1	1/1	1/0	1/0	1/0	1/1	1/0	1/1	1/1	1/0	1/0	1/0	1/1
	2041-2070	1/0	1/0	1/0	1/1	1/1	1/0	1/0	1/0	0/0	1/0	0/0	1/0	1/1	1/0	1/1	0/0	1/1	1/1	1/0	0/0	1/0	1/1	1/0	1/1	1/1	1/0	1/0	1/0	1/1
	2071-2100	0/0	0/0	1/0	1/0	1/0	1/0	1/0	0/0	0/0	0/0	0/0	1/0	1/1	0/0	1/1	0/0	1/0	1/1	0/0	0/0	0/0	1/0	1/0	1/1	1/0	0/0	0/0	1/0	1/0
Jack pine	1971-2000	1/0	1/0	1/0	1/1	1/1	1/1	1/1	1/1	1/0	1/0	1/0	1/1	1/1	1/0	1/0	1/0	1/1	1/1	1/1	1/0	1/1	1/1	1/1	1/1	1/1	1/0	1/0	1/0	1/1
	2011-2040	1/0	1/0	1/0	1/1	1/1	1/1	1/1	1/1	1/0	1/0	1/0	1/1	1/1	1/0	1/0	1/0	1/1	1/1	1/0	1/0	1/0	1/1	1/0	1/1	1/1	1/0	1/0	1/0	1/1
	2041-2070	1/0	1/0	1/0	1/1	1/1	1/1	1/0	1/0	1/0	1/0	0/0	1/0	1/1	1/0	1/1	0/0	1/1	1/1	1/0	0/0	1/0	1/1	1/0	1/1	1/1	1/0	1/0	1/0	1/1
	2071-2100	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	0/0	1/0	0/0	1/0	1/1	1/0	1/1	0/0	1/0	1/1	1/0	0/0	1/0	1/0	1/0	1/1	1/0	1/0	1/0	1/0	1/0
Balsam fir	1971-2000	1/1	1/0	1/1	1/0	1/1	1/1	1/1	1/1	1/0	1/0	1/0	1/1	1/1	1/0	1/0	1/0	1/1	1/1	1/1	1/0	1/1	1/1	1/0	1/1	1/1	1/1	1/0	1/0	1/1
	2011-2040	1/0	1/0	1/0	1/1	1/1	1/1	1/1	1/1	1/0	1/0	1/0	1/1	1/1	1/0	1/0	1/0	1/1	1/1	1/0	1/0	1/0	1/1	1/0	1/1	1/1	1/0	1/0	1/0	1/1
	2041-2070	1/0	1/0	1/0	1/1	1/1	1/1	1/0	1/0	1/0	1/0	0/0	1/0	1/1	1/0	1/1	0/0	1/1	1/1	1/0	0/0	1/0	1/1	1/0	1/1	1/1	1/0	1/0	1/0	1/1
	2071-2100	1/0	0/0	1/0	1/0	1/0	1/0	1/0	1/0	0/0	0/0	0/0	1/0	1/1	0/0	1/1	0/0	1/0	1/1	0/0	0/0	0/0	1/0	1/0	1/1	1/0	1/0	0/0	1/0	1/0
Trembling aspen	1971-2000	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/0	1/1	1/0	1/1	1/1	1/1	1/0	1/0	1/1	1/1	1/1	1/0	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
	2011-2040	1/1	1/0	1/1	1/1	1/1	1/1	1/1	1/1	1/0	1/0	1/0	1/1	1/1	1/0	1/1	1/0	1/1	1/1	1/0	1/0	1/1	1/1	1/1	1/1	1/1	1/1	1/0	1/1	1/1
	2041-2070	1/0	1/0	1/0	1/1	1/1	1/1	1/1	1/1	1/0	1/0	1/0	1/1	1/1	1/0	1/1	1/0	1/1	1/1	1/0	1/0	1/0	1/1	1/1	1/1	1/1	1/0	1/0	1/0	1/1
	2071-2100	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	0/0	1/0	0/0	1/0	1/1	1/0	1/1	0/0	1/1	1/1	1/0	0/0	1/0	1/0	1/0	1/1	1/0	1/0	1/0	1/0	1/0

Species	Time Period	Oak Ridges Moraine	Rouge Park	Niagara Escarpment	Mojikit Lake C. R.	Wabakimi P. P.	Woodland Caribou PP	Willow Lake C. R.	Twilight Lake C. R.	The Pinery P. P.	St. Lawrence I. N. P.	Rondeau P. P.	Quetico P. P.	Pukaskwa N. P.	Presqu'ile P. P.	Polar Bear P. P.	Point Pelee N. P.	Opasquia P. P.	N. of N. French R. C.R.	Natl. Capital Comm.	Long Point P. P.	Lake of the Woods PP	Lady Ev-Smoothwater PP	Killarney P. P.	Kesagami P. P.	Jog Lake C. R.	Georgian Bay I. N. P.	Charleston Lake P. P.	Bruce Peninsula N. P.	Algonquin P. P.
White pine	1971-2000	1/1	1/1	1/1	1/0	1/0	1/0	1/0	1/0	1/1	1/1	1/1	1/1	1/0	1/0	0/0	1/1	1/0	1/0	1/1	1/1	1/0	1/1	1/0	1/0	1/0	1/1	1/1	1/0	1/1
	2011-2040	1/1	1/1	1/1	1/0	1/1	1/0	1/1	1/0	1/0	1/1	1/1	1/1	1/1	1/0	0/0	1/0	1/0	1/1	1/1	1/1	1/0	1/1	1/1	1/0	1/0	1/1	1/1	1/0	1/1
	2041-2070	1/1	1/0	1/1	1/1	1/1	1/0	1/1	1/0	1/0	1/1	1/0	1/1	1/1	0/0	1/0	1/0	1/0	1/1	1/1	1/0	1/0	1/1	1/0	1/1	1/1	1/1	1/1	1/0	1/1
	2071-2100	1/0	1/0	1/1	1/1	1/1	1/0	1/1	1/0	1/0	1/0	1/0	1/1	1/1	0/0	1/0	0/0	1/0	1/1	1/0	1/0	1/0	1/1	1/0	1/1	1/0	1/0	1/0	1/0	1/1
Red pine	1971-2000	1/1	1/1	1/1	0/0	1/0	1/0	1/0	1/1	1/0	1/1	1/0	1/1	1/0	1/0	0/0	1/0	0/0	1/0	1/1	1/0	1/0	1/1	1/1	1/0	1/0	1/1	1/1	1/0	1/1
	2011-2040	1/1	1/0	1/1	1/0	1/1	1/0	1/1	1/1	1/0	1/0	1/0	1/1	1/1	1/0	0/0	1/0	1/0	1/0	1/0	1/0	1/0	1/1	1/1	1/0	1/0	1/1	1/0	1/1	1/1
	2041-2070	1/0	1/0	1/0	1/1	1/1	1/0	1/1	1/1	1/0	1/0	0/0	1/1	1/1	0/0	1/0	0/0	1/0	1/1	1/0	0/0	1/0	1/1	1/0	1/1	1/1	1/0	1/0	1/0	1/1
	2071-2100	1/0	1/0	1/0	1/0	1/1	1/0	1/0	1/0	1/0	1/0	0/0	1/0	1/1	0/0	1/0	0/0	1/0	1/1	1/0	0/0	1/0	1/1	1/0	1/1	1/0	1/0	1/0	1/0	1/0
Sugar maple	1971-2000	1/1	1/0	1/1	0/0	0/0	1/0	1/0	1/0	1/1	1/0	1/1	1/0	1/0	1/0	0/0	1/1	0/0	0/0	1/1	1/1	1/0	1/1	1/0	0/0	0/0	1/1	1/1	1/0	1/1
	2011-2040	1/1	1/0	1/1	0/0	1/0	1/0	1/0	1/0	1/0	1/1	1/1	1/1	1/1	1/0	0/0	1/0	1/0	1/0	1/1	1/1	1/0	1/1	1/0	1/0	1/0	1/1	1/1	1/0	1/1
	2041-2070	1/1	1/0	1/1	1/0	1/1	1/0	1/1	1/0	1/0	1/1	1/0	1/1	1/1	0/0	1/0	1/0	1/0	1/1	1/1	1/1	1/0	1/1	1/0	1/1	1/0	1/1	1/1	1/0	1/1
	2071-2100	1/0	1/0	1/1	1/1	1/1	1/0	1/1	1/0	1/0	1/0	1/0	1/1	1/1	0/0	1/0	0/0	1/0	1/1	1/1	1/0	1/0	1/1	1/0	1/1	1/0	1/1	1/0	1/0	1/1
Red oak	1971-2000	1/1	1/0	1/1	0/0	0/0	0/0	0/0	1/0	1/1	1/0	1/1	1/0	1/0	1/0	0/0	1/1	0/0	0/0	1/1	1/1	1/0	1/0	1/0	0/0	0/0	1/1	1/0	1/0	1/1
	2011-2040	1/1	1/0	1/1	0/0	1/0	1/0	1/0	1/0	1/0	1/1	1/1	1/1	1/0	1/0	0/0	1/0	0/0	1/0	1/1	1/1	1/0	1/1	1/0	0/0	1/0	1/1	1/1	1/0	1/1
	2041-2070	1/1	1/0	1/1	1/0	1/0	1/0	1/0	1/0	1/0	1/1	1/0	1/1	1/0	0/0	0/0	1/0	1/0	1/0	1/1	1/1	1/0	1/1	1/0	1/0	1/0	1/1	1/1	1/0	1/1
	2071-2100	1/0	1/0	1/1	1/0	1/1	1/0	1/1	1/0	1/0	1/0	1/0	1/1	1/1	0/0	1/0	0/0	1/0	1/1	1/1	1/0	1/0	1/1	1/0	1/1	1/0	1/0	1/0	1/0	1/1
Tulip poplar	1971-2000	1/0	1/0	1/0	0/0	0/0	0/0	0/0	0/0	1/0	1/0	1/0	1/0	0/0	0/0	0/0	1/0	0/0	0/0	1/0	1/0	1/0	1/0	1/0	0/0	0/0	1/0	1/0	0/0	1/0
	2011-2040	1/0	1/0	1/0	0/0	0/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	0/0	0/0	1/0	0/0	0/0	1/0	1/0	1/0	1/0	1/0	0/0	0/0	1/0	1/0	1/0	1/0
	2041-2070	1/0	1/0	1/0	0/0	1/0	1/0	1/0	1/0	0/0	1/0	1/0	1/0	1/0	0/0	0/0	0/0	0/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	0/0	0/0	1/0
	2071-2100	1/0	0/0	1/0	1/0	1/0	0/0	1/0	1/0	0/0	0/0	0/0	1/0	1/0	0/0	1/0	0/0	1/0	1/0	1/0	1/0	1/0	1/0	0/0	1/0	1/0	1/0	0/0	0/0	1/0
Black walnut	1971-2000	1/0	1/0	1/0	0/0	0/0	0/0	0/0	0/0	1/0	1/0	1/0	1/0	0/0	1/0	0/0	1/0	0/0	0/0	1/0	1/0	1/0	1/0	1/0	0/0	0/0	1/0	1/0	1/0	1/0
	2011-2040	1/0	1/0	1/0	0/0	0/0	1/0	0/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	0/0	1/0	0/0	0/0	1/0	1/0	1/0	1/0	1/0	0/0	0/0	1/0	1/0	1/0	1/0
	2041-2070	1/0	1/0	1/0	0/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	0/0	1/0	0/0	1/0	1/1	1/0	1/0	1/0	1/0	0/0	1/0	1/0	1/0	1/0	1/0
	2071-2100	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0
Shagbark hickory	1971-2000	1/0	1/0	1/0	0/0	0/0	0/0	0/0	0/0	1/0	1/0	1/0	0/0	0/0	1/0	0/0	1/0	0/0	0/0	1/0	1/0	0/0	0/0	1/0	0/0	0/0	1/0	1/0	1/0	0/0
	2011-2040	1/0	1/0	1/1	0/0	0/0	0/0	0/0	0/0	1/0	1/0	1/0	0/0	1/0	0/0	0/0	1/0	0/0	0/0	1/0	1/0	0/0	0/0	1/0	0/0	0/0	1/0	1/0	1/0	1/0
	2041-2070	1/0	1/0	1/1	0/0	0/0	0/0	0/0	0/0	1/0	1/0	1/0	1/0	1/0	0/0	0/0	1/0	0/0	0/0	1/1	1/0	0/0	1/0	1/0	0/0	0/0	1/0	1/0	1/0	1/0
	2071-2100	1/0	1/0	1/0	0/0	0/0	0/0	0/0	0/0	1/0	1/0	1/0	1/0	1/0	0/0	0/0	0/0	0/0	0/0	1/0	1/0	0/0	1/0	1/0	0/0	0/0	1/0	1/0	1/0	1/1

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